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# Environmental Impact Assessment and Mitigation for UNDEX Testing

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**Defence R&D Canada**  
Technical Memorandum  
DRDC Suffield TM 2010-024  
June 2010

**Canada**



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## Abstract

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In order to assess the environmental impact of underwater explosive disruption trials at DRDC Suffield, the contamination risk was investigated through exposure of water to TNT and RDX. In addition, various filtration techniques were tested to select a viable method of treating contaminated water. After analysis of contaminated and filtered water by High-Performance Liquid Chromatography (HPLC), the explosive concentrations for TNT and RDX were found to be below the Environmental Protection Agency (U.S.) criteria for Risk-Based Concentrations in Soil (Industrial). The relatively brief exposure of water to explosives during an underwater explosion trial was thus found to result in minimal contamination due to the slow dissolution kinetics of the explosives. It is concluded that the environmental impact of water contaminated by underwater explosion testing is minimal when mitigated by: 1) removing residual explosives immediately after a trial, 2) filtering the contaminated water using micron-size filters to remove particulates, and 3) disposing of the water in a sunlit area.

## Résumé

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Afin d'évaluer les répercussions sur l'environnement des essais de neutralisation d'explosifs menés sous l'eau à RDDC Suffield, on a analysé le risque de contamination par l'exposition de l'eau au TNT et au RDX. En outre, diverses techniques de filtration ont été mises à l'essai afin de choisir une méthode viable de traitement des eaux contaminées. Suite à l'analyse de l'eau contaminée et de l'eau filtrée par chromatographie liquide à haute performance (CLHP), on a remarqué que les concentrations de TNT et de RDX étaient inférieures aux normes de l'Environmental Protection Agency (É.-U.) relatives aux concentrations dans le sol (industrielles) fondées sur les risques. Il a été conclu que l'exposition relativement brève de l'eau aux matières explosives lors des essais d'explosions sous-marines produisait une contamination minimale en raison de la lente cinétique de dissolution des explosifs. On peut conclure que l'incidence environnementale de l'eau contaminée par les essais d'explosions sous-marines est minime lorsqu'elle est atténuée par la prise des mesures suivantes : 1) retrait des explosifs résiduels immédiatement après l'essai, 2) filtration de l'eau contaminée au moyen de filtres de l'ordre du micromètre pour retirer les matières particulaires, et 3) évacuation des eaux dans une zone ensoleillée.

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## Executive summary

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### Environmental Impact Assessment and Mitigation for UNDEX Testing

Julian Lee, Gerry Rude, Sonia Thiboutot, Annie Gagnon; DRDC Suffield TM 2010-024; Defence R&D Canada – Suffield; June 2010

**Background:** The present study was motivated by a requirement to perform underwater disruption trials on explosives. The environmental impact of these trials was assessed by experimentally simulating residual explosive contamination of water and investigating impact mitigation procedures.

**Principal results:** The slow dissolution kinetics of TNT and RDX in water provide a significant advantage in maintaining concentration levels below Environmental Protection Agency (U.S.) criteria during an underwater explosion (UNDEX) disruption test. Moreover, TNT and RDX both show rapid degradation within hours when exposed to sunlight, particularly in aqueous solution. The filtered water from UNDEX testing can therefore be disposed of safely in open ground with very low toxicological risk, however solid particles should be filtered from the water.

Micron-size filters tested in this evaluation effectively removed solid particulates, but only activated-carbon filters were found to reduce the amount of dissolved explosives. The amounts of dissolved explosives were reduced by about 25% for an activated carbon-impregnated cellulose 1-5  $\mu\text{m}$  “Taste & Odor Water Filter” (GE®part# FXWTC). Using this type of filter would eliminate particulates larger than a micron and provide the additional benefit of reducing the amount of dissolved explosive.

**Significance of results:** From the current study, it is concluded that the environmental impact of water from underwater explosive disruption testing is minimal when the following mitigated measures are taken:

1. proper filtering with an activated carbon filter with micron-size pores,
2. removing and filtering the water as quickly as possible to take advantage of the slow dissolution rate of explosive,
3. disposal of the water in a sunlit area.

**Future work:** The environmental impact of future explosive tests in water should be evaluated in terms of water temperature and duration of the post-test clean-up procedure. Analysis of contaminated water samples should be performed to ensure they are below U.S. EPA criteria.

# Sommaire

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## Environmental Impact Assessment and Mitigation for UNDEX Testing

Julian Lee, Gerry Rude, Sonia Thiboutot, Annie Gagnon ; DRDC Suffield TM 2010-024 ; R & D pour la d'efense Canada – Suffield ; juin 2010

**Contexte :** La présente étude découle d'un besoin d'effectuer des essais sous-marins de neutralisation d'explosifs. L'impact environnemental de ces essais a été évalué en simulant les contaminations résiduelles des explosifs dans l'eau et en étudiant les procédures d'atténuation des impacts.

**Résultats :** Lors d'un essai de neutralisation d'une explosion sous-marine (UNDEX), les cinétiques lentes de dissolution dans l'eau du TNT et du RDX permettent de maintenir les niveaux de concentration bien en-deçà des limites prescrites par l'Environmental Protection Agency (É.-U.). En effet, le TNT et le RDX démontrent qu'ils se dégradent en à peine quelques heures après avoir été exposés aux rayons du soleil, particulièrement lorsqu'ils se trouvent dans une solution aqueuse. Ainsi, on a conclu que l'eau filtrée des essais UNDEX peut être éliminée de manière sécuritaire en terrain découvert et présente un risque toxicologique très bas; il faut toutefois filtrer les particules solides de l'eau avant d'en disposer.

L'étude conclut que les filtres de l'ordre du micron qui ont été utilisés pour l'essai sont en mesure de filtrer les particules solides, mais que seuls les filtres à charbon actif peuvent réduire la quantité d'explosifs dissous dans l'eau. En effet, lorsqu'une cellulose imprégnée de charbon actif de 1-5 µm « filtre à eau – goût et odeur » (GE no de pièce FXWTC) est utilisée, la quantité d'explosifs dissous est réduite d'environ 25 p. cent. Ainsi, ce type de filtre permet d'éliminer les particules supérieures à un micron en plus de réduire la quantité d'explosif dissous.

**Signification des résultats :** Selon la présente étude, on a déterminé que l'impact environnemental de l'eau provenant des essais sous-marins de neutralisation des explosifs est minimal lorsque les mesures d'atténuation suivantes sont prises :

1. filtrer adéquatement à l'aide d'un filtre à charbon actif dotés de pores de l'ordre du micron;
2. enlever et filtrer l'eau dès que possible pour bénéficier de la vitesse de dissolution lente de l'explosif;
3. éliminer l'eau dans un endroit ensoleillé.

**Mesures à venir :** Il faudrait évaluer l'impact environnemental des futurs essais d'explosifs sous-marins en tenant compte de la température de l'eau et de la durée des procédures de nettoyage après les essais. Une analyse des échantillons d'eau contaminée devrait également être effectuée afin de s'assurer que les niveaux de toxicité se situent en-deçà des limites prescrites par l'EPA des États-Unis.



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# 1 Background

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DRDC Suffield is responding to a request to evaluate the effectiveness of disruption tools against underwater explosive devices [1]. To perform this evaluation, disrupters are tested against underwater explosive devices such as limpet mine facsimiles and submerged explosive charges. In these trials, the explosive inside the device is broken into several pieces and scattered in the water. After a test, there is a risk of residual explosives remaining in the test facility as well as dissolved explosive in the water. In order to clean the facility, it is necessary to remove the residual explosives from the test water and safely dispose of both the explosives and the water to minimize the environmental impact.

In the present study, the environmental impact of these tests was evaluated by experimentally simulating the residual explosives and contaminated water after a test. Explosive-contaminated water samples were produced, and possible mitigation measures such as filtering were investigated. The water samples were analyzed for dissolved chemical residues, and the effectiveness of mitigation measures was determined.

## 2 Experimental Details

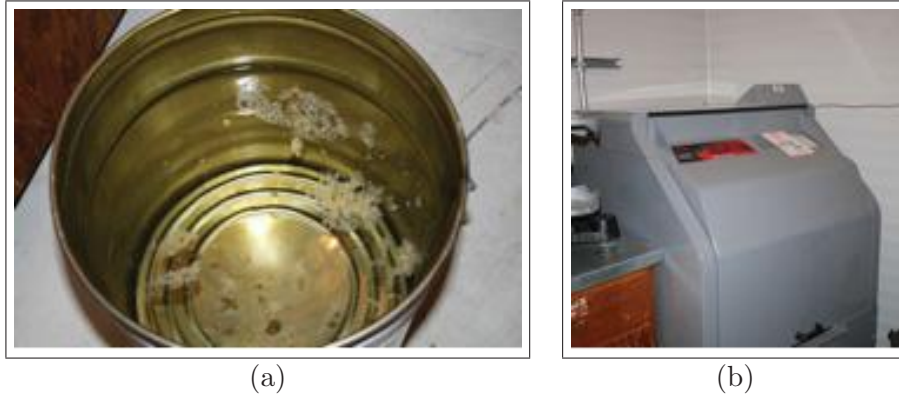
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### 2.1 Explosive-contaminated Water Samples

To simulate the maximum levels of contamination due to an underwater explosion (UNDEX) test where an explosive device is disrupted, granulated explosives were added to clean water and allowed to dissolve. Based on the types of explosives typically found in Limpet Mines, TNT and RDX were chosen as representative contaminants. In a typical UNDEX test involving disruption, a solid explosive charge is broken into a large number of pieces ranging from several centimeters [1] to less than a millimeter in size. These pieces are dispersed in the surrounding water within milliseconds, then allowed to sit in the water for a 5 to 30-minute waiting period to allow field trial officers and explosive technicians to establish that the test site is safe. The solid pieces of explosive are then gathered for later disposal, and the explosive-contaminated water is evacuated.

To produce representative contaminated water samples, TNT flake and RDX powder were added to approximately 10 liters of tap water at a temperature of 17.8°C in a 20-liter bucket (Figure 1a). Approximately 1.3 g. of TNT and 0.4 g. of RDX were added to the water. The amounts of explosive were chosen such that they exceeded the saturation levels at 20°C, i.e. 130 mg/L for TNT and 42 mg/L for RDX [2]. The mixture was then shaken in a paint can mixer for approximately 10 minutes (Figure 1b).

After mixing, a sample of the mixed solution was filtered using a Whatman Qualitative Grade#1 paper with 27  $\mu\text{m}$  pores (Figure 2) to remove solid particulates. The mixed solution was then left in storage at 8.7°C for 12 days, then further stirred to increase dissolution of the explosive. The solution was then passed through various filtering arrangements to test their effectiveness.



**Figure 1:** Contaminated water sample preparation showing a) TNT flakes and RDX powder in the water, and b) paint can mixer.



**Figure 2:** Paper filter arrangement for removing solid particles.

Six samples were produced as listed in Table 1. The samples were designed to represent different levels of water contamination as well as the results of different filtering procedures.

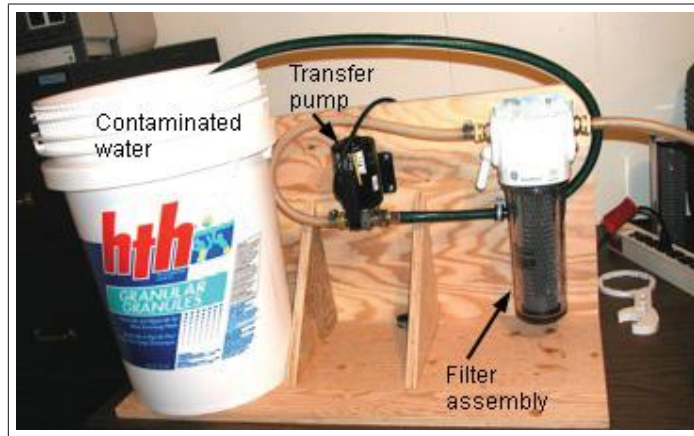
## 2.2 Water Decontamination System

To mitigate the environmental impact of disposing of water containing residual explosives from UNDEX testing, a filtration system was developed to partially remove the explosives from the water. First, a bench-top system was designed for testing and evaluating the performance of various filters. It consisted of a pump to circulate the contaminated water samples through different types of commercially-available filters such as polypropylene-fiber or activated charcoal filters. The filtered water was then analyzed for residual explosive content. The results from the filtering tests were subsequently used to design a larger system for field use.

**Table 1:** Samples for water analysis.

Sample	Filtration method	Dissolution time	Temperature	Abbreviated description
A	27 $\mu\text{m}$ paper filter	10 min	17.8°C	27 $\mu\text{m}$ (10min)
B	20 $\mu\text{m}$ fiber filter	12 days	8.7°C	20 $\mu\text{m}$
C	Unfiltered	12 days	8.7°C	saturated
D	1-5 $\mu\text{m}$ activated carbon filter	12 days	8.7°C	1-5 $\mu\text{m}$ AC
E	Blank (clean water)	12 days	8.7°C	Blank
F	20 $\mu\text{m}$ fiber filter followed by 1-5 $\mu\text{m}$ activated carbon filter	12 days	8.7°C	20 $\mu\text{m}$ & 1-5 $\mu\text{m}$ AC

The bench top water filtration arrangement consisted of a transfer pump coupled to a household filtration assembly. The water was filtered through two types of filters: a polyspun (polypropylene) depth filter cartridge with 20  $\mu\text{m}$  pores for sediment filtering (GE® part# FXUSC), and an activated carbon-impregnated cellulose 1-5  $\mu\text{m}$  “Taste & Odor Water Filter” (GE® part# FXWTC). The entire filtration assembly is shown in Figure 3.



**Figure 3:** Bench-top water filtration arrangement.

## 3 Results

### 3.1 Sample Analysis

All filters were found to effectively remove the visible solid particulates from the water samples (Table 1). To analyze the dissolved explosive, the samples were sent to DRDC Valcartier for analysis using a High-Performance Liquid Chromatography (HPLC) instrument. The resulting amounts of RDX and TNT detected in the water samples are shown in Table 2, where “ppm” indicates parts-per-million.

**Table 2:** Detection of RDX and TNT in samples.

Sample	Description	RDX (ppm)	TNT (ppm)
A	27 $\mu\text{m}$ (10min)	4.23	5.71
B	20 $\mu\text{m}$	15.15	20.75
C	saturated	15.47	20.81
D	1-5 $\mu\text{m}$ AC	11.52	15.76
E	Blank	0.00	0.00
F	20 $\mu\text{m}$ & 1-5 $\mu\text{m}$ AC	12.63	15.73

The amounts of TNT and RDX were found to be well below the theoretical saturated amounts of 130 ppm for TNT and 42 ppm for RDX at 20°C [2]. This is partially due to the lower water temperature of 8.7°C. For Sample A taken within 20 minutes of the explosive being added, less than 6 ppm of TNT and less than 5 ppm of RDX were dissolved, confirming the slow dissolution rate of the explosives. Even after 12 days, the levels remained below 21 ppm for TNT and below 16 ppm for RDX, as seen in the unfiltered water results (sample C). When filtered using the 20  $\mu\text{m}$  polypropylene filter (sample B), the water showed no significant decrease in the amount of dissolved explosive. However, the 1-5- $\mu\text{m}$  activated carbon filter reduced the concentration by approximately 25% for the dissolved TNT and RDX.

In addition to the main contaminants of RDX and TNT, eleven additional compounds were tested for: HMX; 1,3,5-TNB; 1,3-DNB; TETRYL; NG; 2,4-DNT; 2,6-DNT; 2-A-DNT; 4-A-DNT; 2+4-NITRO; 3-NITRO. These compounds were included as part of a standard analysis for environmental contamination by explosives. The abbreviations stand for:

**HMX** : cyclotetramethylene-tetranitramine, tetrahexamine tetranitramine, or octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocane

**TNB** : trinitrobenzene

**DNB** : dinitrobenzene

**TETRYL** : 2,4,6-trinitrophenyl-N-methylnitramine

**DNT** : dinitrotoluene

**NITRO** : nitrotoluene

Although only TNT and RDX were added to the water, trace amounts of these other compounds were found. The amounts of DNB, TETRYL, NG, 2,6-DNT, and NITRO were found to be below the detectable limit. The amounts of the remaining compounds are shown in Table 3. When the amount is below the detection limit of the HPLC, the value is denoted “n.d.”, i.e. not detectable, and “ppb” indicates parts-per-billion.

**Table 3:** Detection of HMX, TNB and DNT in samples.

Sample	Description	HMX (ppb)	1,3,5-TNB (ppb)	2,4-DNT (ppb)	2-A-DNT (ppb)	4-A-DNT (ppb)
A	27 $\mu\text{m}$ (10min)	83.40	n.d.	9.00	18.42	65.73
B	20 $\mu\text{m}$	306.95	4.79	28.02	35.10	79.89
C	saturated	468.60	6.91	39.67	51.92	104.56
D	1-5 $\mu\text{m}$ AC	346.70	4.72	26.46	34.33	77.07
E	Blank	n.d.	n.d.	n.d.	n.d.	n.d.
F	20 $\mu\text{m}$ & 1-5 $\mu\text{m}$ AC	346.72	4.35	n.d.	n.d.	71.91

The presence of these compounds is likely due to impurities in the TNT and RDX added to the explosive, or to partial decomposition of the main explosives.

## 3.2 Dissolution Process

The dissolution of explosives in water is driven by diffusive mass transfer through the boundary layer formed as water flows over the surface of the explosive. The process can be described by an expression derived from Fick’s First Law[3]:

$$V \frac{dC}{dt} = \frac{D}{h} a (C_s - C_b) \quad (1)$$

where  $V$  is the solvent volume,  $C$  is the concentration,  $D$  is the diffusion coefficient,  $h$  is the stagnant fluid layer thickness,  $a$  is the surface area,  $C_s$  is the solubility, and  $C_b$  is the concentration in the bulk liquid. The dissolution thus depends on temperature through the solubility, the surface area which is related to the particle size of granulated explosives, the mixing rate which is related to the stagnant layer, the volume of solvent, and the dissolution time. The pH of the water was also found to have a small effect on the solubility [4].

The dissolution of explosives depends strongly on the water temperature, and is typically correlated with an exponential trend line. Phelan et. al. [5] measured the solubility of Composition B, an explosive containing approximately 60% RDX and 40% TNT by mass. The explosive was ground into micron-size particles inside a ball mill, and separated into

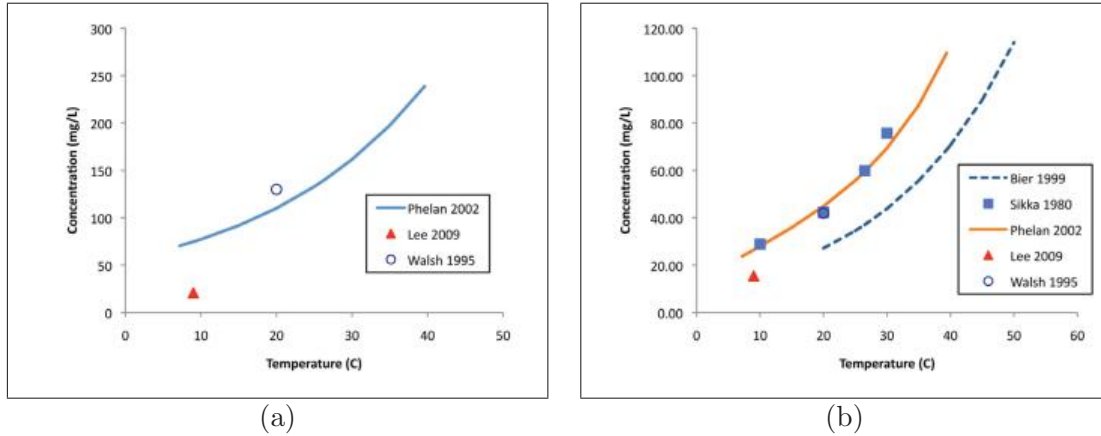
three size ranges using sieves: 90-106  $\mu\text{m}$ , 500-600  $\mu\text{m}$ , and 1000-1180  $\mu\text{m}$ . The explosive was added to water and the solutions were stirred in an Erlenmeyer flask immersed in a temperature-controlled bath with a teflon-coated magnetic stir bar until equilibrium was reached. The solution was subsequently analyzed using HPLC to determine the explosive concentration. The solubility correlation for TNT was found to be:

$$C = 20.176 + 36.295e^{-T/-22.061} \quad (2)$$

where  $C$  is the concentration in mg/liter, and  $T$  is the temperature in  $^{\circ}\text{C}$ . The solubility correlation for RDX was found to be:

$$C = \{0.0804 - 0.0194\ln(T)\}^{-1} \quad (3)$$

Both the correlations are validated with experimental data in the temperature range from  $7.2^{\circ}\text{C}$  to  $39.4^{\circ}\text{C}$ . These solubility correlations are shown as a function of temperature in Figure 4. The frequently-referenced values of solubility from Walsh et. al. [2] are included for comparison, as well as the Sample C concentrations from Table 2 of the current work (labelled Lee 2009). The samples produced in this work are clearly well below saturation levels. This can be attributed to the slow dissolution kinetics of the explosives in question.



**Figure 4:** The solubility of a) TNT and b) RDX in water as a function of temperature.

The dissolution rate, as described in Eq. 1, is a function of two main time-dependent parameters: the decreasing surface area of the explosive as it dissolves, and the increasing concentration explosive in solution. The dissolution flux rate for a fixed temperature and mixing rate was determined by Phelan et. al. [5] by defining:

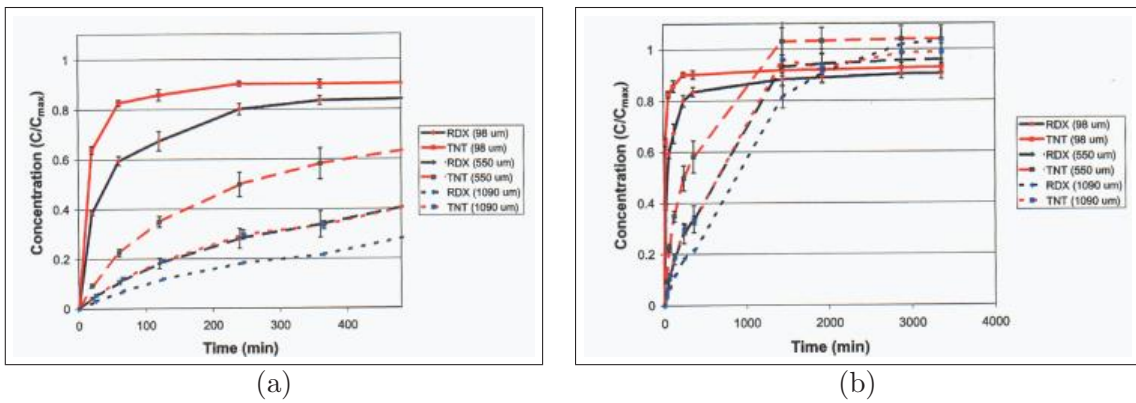
$$r_i = \frac{\Delta M_i}{\Delta t a_i} \quad (4)$$



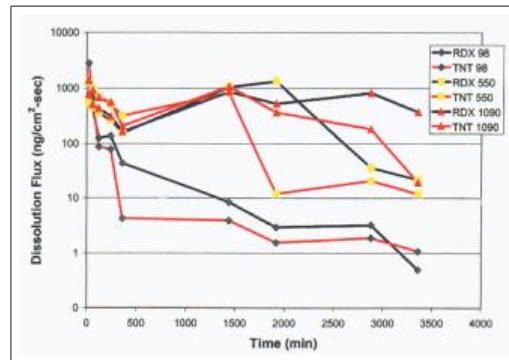
where  $r_i$  is the dissolution rate,  $\Delta M_i$  is the total change in explosive mass at the end of time interval  $i$ ,  $\Delta t$  is the difference in time for the interval, and  $a_i$  is the total surface area of the explosive. The total change in explosive mass is further given by:

$$\Delta M_i = \Delta C_i V \quad (5)$$

where  $\Delta C_i$  is the change in concentration of the interval  $i$  and  $V$  is the volume of the solution. The concentration and volume were measured at regular intervals, and the change in area was estimated assuming spherical particles of a uniform size and fixed number. The results showed that for 98  $\mu\text{m}$  particles, the concentration of the solution reached saturation within 4-5 hours (Fig. 5a), and for larger particles of 550  $\mu\text{m}$  and 1090  $\mu\text{m}$ , saturation was reached after approximately 20 hours and 60 hours respectively. Given these slow dissolution rates, it is understandable that the water samples produced in this study were well below saturation (Fig. 4), particularly with the limited mixing and dissolution time allowed. Phelan et. al. [5] also estimated the dissolution flux rate for different particle sizes in their study (Fig. 6), again showing slow dissolution kinetics with rates below 1  $\text{ng}/\text{cm}^2 \cdot \text{sec}$ .



**Figure 5:** Dissolution rates for RDX and TNT in water from Phelan et. al. [5].



**Figure 6:** Dissolution flux rate for different particle sizes [5].

The dissolution rates for dilute mixtures were studied by Lynch et. al. [3]. The expression for diffusion-based dissolution based on Fick's law (Eq. 1) can be reduced to a zero-order equation by making a number of simplifying assumptions. The assumptions are that the concentration of the bulk liquid  $C_b$  is negligible compared to the saturation concentration  $C_s$ , the surface area  $a$  is constant, the solution volume  $V$  is constant, and finally that the stagnant layer  $h$  is constant. The stagnant layer  $h$  is analogous to the boundary layer formed as the water flows over the solid explosive. It is indeed nearly constant, as it is a weak function of flow velocity particularly for turbulent boundary layers at high Reynold's numbers above  $10^5$ , where it is proportional to the free-stream velocity to a  $-1/5th$  or  $-1/7th$  power [6]. To produce dissolution data, the solutions were mixed using a Yamato Scientific StedFast Digital Lab Stirrer comprising a small rotating impeller lowered into the solution. It was subsequently possible to fit linear regressions to dissolution data, yielding the following correlations for the rates  $r$ :

$$r = (9.82 \times 10^{-6}T - 4.0 \times 10^{-5})am \quad (6)$$

for TNT where  $r$  is the dissolution rate in mg/min,  $T$  is the temperature in degrees C,  $a$  is the surface area in  $\text{cm}^2$ , and  $m$  is the mixing rate in revolutions per minute (rpm), and:

$$r = (1.49 \times 10^{-6}T - 6.1 \times 10^{-6})am \quad (7)$$

for RDX. These correlations are validated against experimental data for the following ranges of conditions:

$$\begin{aligned} 10^\circ\text{C} < T < 30^\circ\text{C}, \\ 90 \text{ rpm} < m < 250 \text{ rpm}, \text{ and} \\ 5 \text{ cm}^2 < a < 12 \text{ cm}^2. \end{aligned}$$

Using the correlations of Eqs. 6 and 7, the explosive concentrations were estimated for the water samples produced in the present study. Only sample A in Table 1 was used, as it had a known mixing time of 10 min. The other samples (B-F) were not stirred for 12 days, and it was not possible to estimate mixing during this period. For sample A, the vigorous mixing provided by the paint can shaker was assumed to be equivalent to a stirring device rotating at 250 rpm. The surface area was estimated using surface area to mass ratios given in Phelan et. al. [5]:

$$\begin{aligned} \text{RDX powder: } 100.4 \text{ cm}^2/\text{g} \\ \text{TNT flake: } 23.28 \text{ cm}^2/\text{g}. \end{aligned}$$

The TNT and RDX concentrations for sample A were estimated at 1.0 ppm and 0.2 ppm respectively. These values are well below the measured values of 5.71 ppm for TNT and 4.23 ppm for RDX shown in Table 2. The cause for the high concentration levels in sample A are not known, however a possible explanation is that small particles of explosive passed through the  $27 \mu\text{m}$  paper filter and dissolved during the period of about three weeks between the time the sample was taken and the time it was analyzed by HPLC. It is also possible

that all samples taken in the present work might have contained small micron-size particles of explosives before being sent for analysis. The water analysis results of Tables 2 and 3 therefore represent upper bounds for the dissolved explosive levels.

In an actual UNDEX test, the residual explosive and contaminated water are collected and evacuated typically within an hour of the test. The concentrations of dissolved TNT and RDX would likely be much lower than the values in Tables 2 and 3 due to the slow dissolution kinetics. There is therefore a significant benefit in treating and disposing of the contaminated water within a minimal time delay after an UNDEX test. Furthermore, the concentration levels are likely to remain low even after a delay of several hours, particularly in the absence of active mixing.

### 3.3 Contamination Levels

If the filtered contaminated water is disposed of in the soil, the results can be interpreted in the context of soil contamination and toxicological hazards. Soil contamination criteria were sought, and it was found that none exist in Canada. As the next best alternative, the industrial standards established by the Environmental Protection Agency (EPA) in the United States were used as guidelines. The risk-based concentrations are reproduced in Table 4.

**Table 4:** Risk-Based Concentrations in Soil[7].

Analyte	Industrial (ppm)	Residential (ppm)
TNT	95	21
RDX	26	5.8
HMX	51,000	3,900
NG	200	46
2,4-DNT	2000	160
2,6-DNT	1000	78

As shown in Table 4, EPA criteria for TNT and RDX are 95 ppm and 26 ppm respectively for industrial grounds. These values are well above the values found for all water samples tested in this study (Table 2). The water filtered within 10 minutes of the test showed the lowest amounts of dissolved explosives at under 6 ppm. Even unfiltered water allowed to sit for 12 days showed levels of less than 21 ppm, again below the criteria for both RDX and TNT. Since the Explosion Proving Grounds on which the UNDEX test facilities are located can be considered an industrial area, the filtered water easily meets the U.S. EPA standards.

Although filtering the water using a 1-5  $\mu\text{m}$  activated carbon filter reduced the concentrations of dissolved explosive by approximately 25%, this measure is not necessary provided the water is filtered to remove solids within hours of the trial.

## 4 Conclusions

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The slow dissolution kinetics of TNT and RDX in water provide a significant advantage in maintaining concentration levels below EPA criteria during an UNDEX disruption test. Moreover, TNT and RDX both show rapid degradation within hours in both aqueous solution and in air when exposed to sunlight [10]. Specifically, the photolytic half-life of TNT in water is 0.16-1.28 hours, and 3.7-11.3 hours in air when exposed to direct sunlight [8], and can be further consumed through microbial degradation. For RDX, the photolytic half-life in aqueous solution is 9-13 hours [9]. The filtered water from UNDEX testing can therefore be disposed of safely in open ground with very low toxicological risk, however solid particles should be filtered from the water first.

Micron-size filters tested in this evaluation effectively removed solid particulates, but only activated-carbon filters were found to reduce the amount of dissolved explosives. The amounts of dissolved explosives were reduced by about 25% for an activated carbon-impregnated cellulose 1-5  $\mu\text{m}$  "Taste & Odor Water Filter" (GE  $\text{\textcircled{R}}$  part# FXWTC). Using this type of filter can eliminate particulates larger than a micron and provide the additional benefit of reducing the concentration of dissolved explosive.

From the current study, it can be concluded that the environmental impact of water from underwater explosive testing is minimal when the following mitigated measures are taken:

1. removing and filtering the water as quickly as possible to take advantage of the slow dissolution rate of explosive,
2. proper filtering with an activated carbon filter with micron-size pores,
3. disposal of the water in a sunlit area.

## Acknowledgements

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The authors gratefully acknowledge the guidance of John Anderson in coordinating sample mixing and analysis, Pat Lambert and Louis Gagné for performing the explosive mixing, the collaborative spirit and assistance of S. Thiboutot and A. Gagnon at DRDC Valcartier, and the valuable input from Jerome Fitzgerald, the Environmental Officer at DRDC Suffield.

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(Security classification of title, body of abstract and indexing annotation must be entered when document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.)  <b>Defence R&amp;D Canada – Suffield                  Box 4000, Station Main, Medicine Hat, Alberta,                  Canada T1A 8K6</b>		2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.)  <b>UNCLASSIFIED                  (NON-CONTROLLED GOODS)                  DMC A                  REVIEW: GCEC December 2013</b>	
3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)  <b>Environmental Impact Assessment and Mitigation for UNDEX Testing</b>			
4. AUTHORS (Last name, followed by initials – ranks, titles, etc. not to be used.)  <b>Lee, J.; Rude, G.; Thiboutot, S.; Gagnon, A.</b>			
5. DATE OF PUBLICATION (Month and year of publication of document.)  <b>June 2010</b>	6a. NO. OF PAGES (Total containing information. Include Annexes, Appendices, etc.)  <b>26</b>	6b. NO. OF REFS (Total cited in document.)  <b>10</b>	
7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)  <b>Technical Memorandum</b>			
8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)  <b>Defence R&amp;D Canada – Suffield                  Box 4000, Station Main, Medicine Hat, Alberta, Canada T1A 8K6</b>			
9a. PROJECT NO. (The applicable research and development project number under which the document was written. Please specify whether project or grant.)	9b. GRANT OR CONTRACT NO. (If appropriate, the applicable number under which the document was written.)		
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.)  <b>DRDC Suffield TM 2010-024</b>	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)		
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In order to assess the environmental impact of underwater explosive disruption trials at DRDC Suffield, the contamination risk was investigated through exposure of water to TNT and RDX. In addition, various filtration techniques were tested to select a viable method of treating contaminated water. After analysis of contaminated and filtered water by High-Performance Liquid Chromatography (HPLC), the explosive concentrations for TNT and RDX were found to be below the Environmental Protection Agency (U.S.) criteria for Risk-Based Concentrations in Soil (Industrial). The relatively brief exposure of water to explosives during an underwater explosion trial was thus found to result in minimal contamination due to the slow dissolution kinetics of the explosives. It is concluded that the environmental impact of water contaminated by underwater explosion testing is minimal when mitigated by: 1) removing residual explosives immediately after a trial, 2) filtering the contaminated water using micron-size filters to remove particulates, and 3) disposing of the water in a sunlit area.

Afin d'évaluer les répercussions sur l'environnement des essais de neutralisation d'explosifs menés sous l'eau à RDDC Suffield, on a analysé le risque de contamination par l'exposition de l'eau au TNT et au RDX. En outre, diverses techniques de filtration ont été mises à l'essai afin de choisir une méthode viable de traitement des eaux contaminées. Suite à l'analyse de l'eau contaminée et de l'eau filtrée par chromatographie liquide à haute performance (CLHP), on a remarqué que les concentrations de TNT et de RDX étaient inférieures aux normes de l'Environmental Protection Agency (É.-U.) relatives aux concentrations dans le sol (industrielles) fondées sur les risques. Il a été conclu que l'exposition relativement brève de l'eau aux matières explosives lors des essais d'explosions sous-marines produisait une contamination minimale en raison de la lente cinétique de dissolution des explosifs. On peut conclure que l'incidence environnementale de l'eau contaminée par les essais d'explosions sous-marines est minime lorsqu'elle est atténuée par la prise des mesures suivantes : 1) retrait des explosifs résiduels immédiatement après l'essai, 2) filtration de l'eau contaminée au moyen de filtres de l'ordre du micromètre pour retirer les matières particulaires, et 3) évacuation des eaux dans une zone ensoleillée.

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Explosive contamination  
Environmental impact  
UNDEX  
Explosive dissolution





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