

To: Nunavut Water Board
From: Shear Diamonds Ltd.
Date: August 15, 2011
Ref: Jericho Diamond Mine, 2AM-JER0410

Final Specifications of the Hydrocarbon Contact Water Remediation Unit (Oztek®)

**2AM-JER0410 Renewal Application Technical Meeting June 20-21, 2011,
Jericho Diamond Mine, Nunavut**

This technical memorandum is being submitted in response to the request made, during the Technical Meeting and Pre-Hearing Conference held in Cambridge Bay, for the final specifications of the unit designed to treat hydrocarbon contaminated contact water. As follow up to those discussions, and in response to intervener's technical submissions, Shear Diamonds Ltd. ("Shear") is pleased to provide the Nunavut Water Board with the following information.

Hydrocarbon contaminated contact water is created within fuel and waste containment berms as well as within landfarm sumps as detailed in the Landfarm Management Plan submitted for review in February 2011. Under previous stewardship, the hydrocarbon contaminated water (F1-F4 ranging from 0.2 to 29.4 mg/l) was discharged directly to the Process Kimberlite Containment Area (PKCA) without treatment.

Shear will treat hydrocarbon contaminated water prior to discharge to the PKCA. Waters that are treated are held in a specific clean berm and tested prior to batch discharge. The criterion the treated water is compared against prior to discharge is Federal Interim Groundwater Quality Guidelines, Commercial/Industrial Land Use and Freshwater Aquatic Life. Shear will continue to monitor pre and post treatment water quality to gauge effectiveness of the unit on waters of different contamination levels.

To date, the contact water treatment has been conducted on hydrocarbon contaminated waters from Phase 1 and Phase 2 containment berms of the fuel farm area. The Oztek® was successful in treating the water and reduced the F3 fraction to below detection levels.

The sample results from before and after treatment to date are shown in Table 1. The batch sample results from the clean berm prior to discharge are shown in Table 2.

Table 1: Results from treatment of contact water

ALS		Sample ID		OZTEC BEFORE TREATMENT-TANK FARM	OZTEC AFTER TREATMENT-TANK FARM	OZTEC FIELD BLANK-TANK FARM
8/11/2011		ALS ID		L1034712-1	L1034712-2	L1034712-3
L1034712		Date Sampled		7/20/2011	7/20/2011	7/20/2011
Analyte	Units	LOR	Fed-CIL-T2-C-FWAL	Water	Water	Water
Benzene	mg/L	0.0005	0.69	<0.00050	<0.00050	<0.00050
Ethylbenzene	mg/L	0.0005	41	<0.00050	<0.00050	<0.00050
Toluene	mg/L	0.0005	0.083	0.00059	0.00066	0.00093
o-Xylene	mg/L	0.0005	-	0.00139	<0.00050	<0.00050
m+p-Xylene	mg/L	0.0005	-	0.00182	<0.00050	<0.00050
Xylenes	mg/L	0.00071	18	0.00322	<0.00071	<0.00071
F1(C6-C10)	mg/L	0.1	9.8	<0.10	<0.10	<0.10
F1-BTEX	mg/L	0.1	9.8	<0.10	<0.10	<0.10
F2 (>C10-C16)	mg/L	0.25	1.3	0.37	<0.25	<0.25
F3 (C16-C34)	mg/L	0.25	-	2.6	<0.25	<0.25
F4 (C34-C50)	mg/L	0.25	-	<0.25	<0.25	<0.25
Applied Guideline:	Federal Interim Groundwater Quality Guidelines (May, 2010) - Federal Commercial & Industrial Land Use-Tier 2-Coarse-Freshwater Aquatic Life					
Color Key:	Within Guideline					

Table 2: The results of sampling from the clean berm prior to discharge to the PKCA

ALS		Sample ID		OZTEK AFTER TREATMENT BATCH BERM
8/11/2011		ALS ID		L1039917-1
L1039917		Date Sampled		08/03/2010
Analyte	Units	LOR	Fed-CIL-T2-C-FWAL	Water
Benzene	mg/L	0.0005	0.69	<0.00050
Ethylbenzene	mg/L	0.0005	41	<0.00050
Toluene	mg/L	0.0005	0.083	<0.00050
o-Xylene	mg/L	0.0005	-	<0.00050
m+p-Xylene	mg/L	0.0005	-	<0.00050
Xylenes	mg/L	0.00071	18	<0.00071
F1(C6-C10)	mg/L	0.1	9.8	<0.10
F1-BTEX	mg/L	0.1	9.8	<0.10
F2 (>C10-C16)	mg/L	0.25	1.3	<0.25
F3 (C16-C34)	mg/L	0.25	-	<0.25
F4 (C34-C50)	mg/L	0.25	-	<0.25
Applied Guideline:	Federal Interim Groundwater Quality Guidelines (May, 2010) - Federal Commercial & Industrial Land Use-Tier 2-Coarse-Freshwater Aquatic Life			
Color Key:	Within Guideline			



The remediation unit (Oztek®) was designed by Ketek Industries with collaboration of Shear personnel and was manufactured by Westland/Ketek Manufacturing. It is located at the mine site and is functioning as intended.

The Oztek® Water Decontamination Process - *Technology Overview* will be appended to the Site Water Management Plan (EBA, 2011), the Landfarm Management Plan (EBA, 2011) and the Waste Management Plan (EBA, 2011).

OZTEK[®] WATER DECONTAMINATION PROCESS

Technology Overview



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SUMMARY

The process is designed to *remove and destroy* hydrocarbons that are present in contaminated water. The removal is achieved by *aeration*, also known as air stripping, where the contaminants are transferred from the water to many small air bubbles introduced into the water. The destruction is achieved by *oxidation* using ozone, where the hydrocarbons are converted into water and carbon dioxide. The overall chemistry involved is identical to that of burning or incineration, except that it occurs at a low temperature and in a liquid phase.

Additional “fine polishing” filters are also provided to remove suspended solids that are present in the inlet liquid or formed in the process, and also residual hydrocarbons that are not completely removed or destroyed. These, respectively, are removed by filtration and adsorption using activated carbon.

DESCRIPTION OF SYSTEM AND ITS OPERATION¹

A schematic diagram of the system is shown in Figure 1. The main components and their corresponding functions are summarized below:

- **Aeration Tank (A) and Aerator (A1):** Small air bubbles are generated and dispersed into the liquid in the tank. The contaminants, often referred to as volatile organic compounds (VOCs), are “stripped”, meaning transferred from the liquid to the bubbles, as will be described later.
- **Ozonation Tank (B) and Ozone Generator (B1):** Ozone (O_3) is generated by passing dried air across an electric discharge (simulating lighting) and drawn to the tank via suction created by a venturi through which recirculation water is passed. The recirculation water is pumped using the **Recirculation Pump (D)** from the aeration tank to the ozonation tank. The VOCs react with O_3 to form water (H_2O) and carbon dioxide (CO_2), as will be described later. The overflow from the ozonation tank returns to the aeration tank.
- **Polishing Filters (C):** After the aeration and ozonation steps are completed in the batch operation (see operation below), the treated water is discharged using the **Discharge Pump (E)** through a pair of polishing filters², each of which consists of a 1-micron filter to remove suspended solids, and two activated carbon beds to adsorb residual contaminants.

The batch operation is as follows:

- **STEP 1 – PREPARATION AND FILL-UP (Manual):** After satisfactory pre-inspection as described in the manual, the contaminated water is pumped (using owner’s pump, not shown) into the aeration tank, with the **Level Equalizer (F) valve** open. When the desired volume is pumped in or the tank is full, the pumping is stopped, the inlet valve is closed, and the **START BUTTON in the CONTROL PANEL** (not shown) is pressed to activate the *automated operation* described in the following.

¹ Details are given in the Operating Manual. Only the initial batch mode operation is described. Continuous operation can be done when more operating experienced has been gained.

² This allows maintenance or replacement of one while the other is used in the operation. Both sets can also be used at the same time.

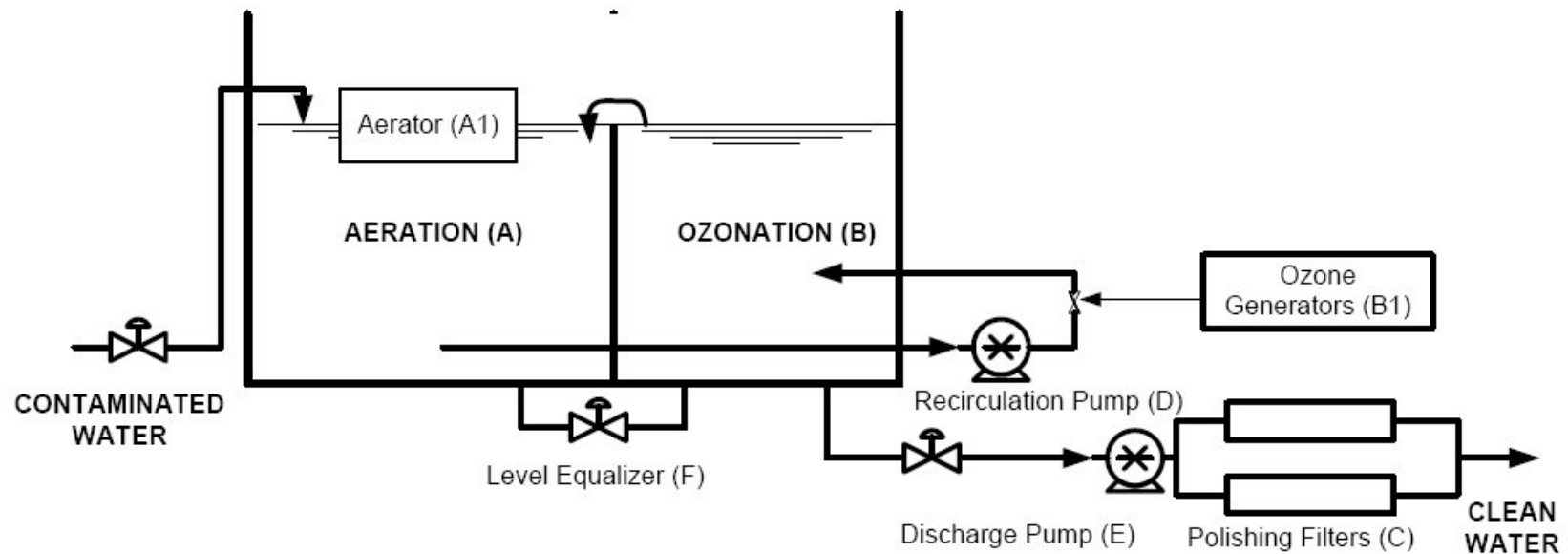


Figure 1. Schematic Diagram of Oztek® Water Decontamination System

- **STEP 2 – AERATION and OZONATION FOLLOWED by DISCHARGE (Automated).** The aeration and ozonation are started automatically and take place over a pre-set time (adjustable), and then the treated water is discharged to the **DISCHARGE RESERVOIR** (owner's responsibility, not shown) via the one or two of the polishing filters.

Note therefore that except for the initial fill-up step, the process is executed automatically, requiring minimum operator intervention.

REMOVAL and DESTRUCTION MECHANISMS

This section is intended to satisfy a layman's curiosity, not an academic, scholarly treatise.

Aeration or Air Stripping

When contaminated water comes in contact with air, an "equilibrium state" will eventually be reached, where the contaminant concentrations in the water, C_W , and in the air, C_A , are related by $C_A = k(T) * C_W$, as shown in Figure 2 (A). The "constant" $k(T)$ depends on the contaminant AND temperature.³

In the process, air bubbles, which *initially* contains no contaminant, that is $C_A = 0$, are introduced into the contaminated water. A "driving force" is thus created, to transfer contaminants from the water to the air so that the equilibrium state can be reached. The contaminants are "stripped" from the water to the air; see Figure 2 (B).

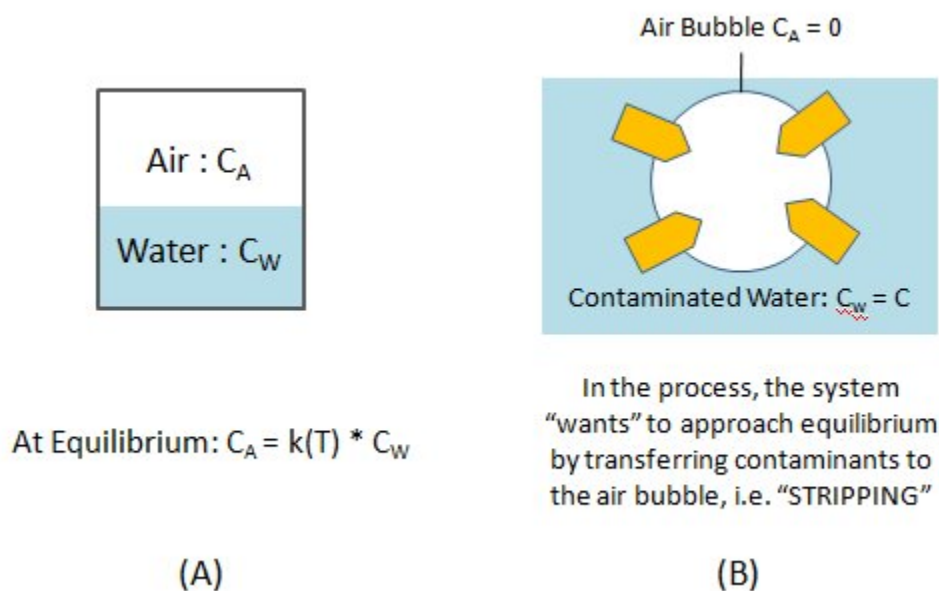


Figure 2. Simplified Mechanism of Aeration or Air Stripping

The effectiveness of the process, at a given temperature, depends on the following factors: (i) the contact area between the air and the water, and (ii) the extent of "turbulence" or mixing in the liquid phase, and (iii) the time allowed for the process to occur. There are different ways of contacting the liquid and the air, each with its own advantages and disadvantages.⁴

³ This is often referred to as Henry's or Raoult's law with concentrations expressed in different terms, such as partial pressure and molar quantities. http://en.wikipedia.org/wiki/Henry's_law

⁴ See for example <http://www.frtr.gov/matrix2/section4/4-46.html>

The technology is well established and have been successfully used for removing hydrocarbons, including BTEX (benzene, toluene, ethyl benzene and xylene) and various chlorinated VOCs, and in general, contaminants with a Henry law constant higher than 0.01 atm/(mol/m³).⁴ The particular process design selected here was chosen on the basis on cost and simplicity in operation and maintenance, taking into account the applicable site specific conditions.

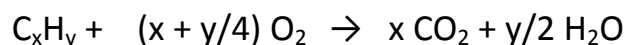
Ozonation

Ozone is O₃ as compared to oxygen in air that we breathe, O₂. It is formed naturally by ultra-violet radiation and by electrical discharges (lighting). It is an unstable compound, with a half-life of 20 – 30 minutes in water at (20 – 15 C), producing the so-called OH-radicals.⁵ It is for this reason than ozone is a very strong oxidizer when used in waste water treatment. The following table shows the “redox” potential values of various oxidizing agents, the numerical values of which can be interpreted as their oxidizing “strengths”.⁶

Substance	Potential (V)
Fluorine (F)	2,87
Hydroxyradical (OH)	2,86
Oxygen atom (O)	2,42
Ozone molecule (O ₃)	2,07
Hydrogen peroxide (H ₂ O ₂)	1,78
Chlorine (Cl)	1,36
Chlorine dioxide (ClO ₂)	1,27
Oxygen molecule (O ₂)	1,23

Ozone and its byproduct in water, hydroxyradical, are stronger than some other commonly used oxidizing agents, such as hydrogen peroxide, chlorine and oxygen.

The destruction of hydrocarbons by ozone is, in the *overall outcome* but not in detailed step-by-step mechanisms, identical to what happens in burning or incineration.



In addition being a strong oxidizer, ozone has the following advantages:

- It can be generated on-site, thereby eliminating transportation and storage costs;
- Compared to chlorine, no toxic chlorinated by-products are formed.

⁵ <http://www.lenntech.com/library/ozone/decomposition/ozone-decomposition.htm>

⁶ <http://www.lenntech.com/library/ozone/reaction/ozone-reaction-mechanisms.htm>

Adsorption on Activated Carbon

Activated carbon is produced from carbonaceous materials, including charcoal and coconut shells, by heating (up to 900 C) and the application of steam and various chemicals. The product can be in various forms, such as powdered, granular and extruded.

There are two relevant characteristics of activated carbon for this application:

- large surface area, in the range of 500 – 1500 m²/g; and
- ability to adsorb contaminants on its surface.

Photographs of powdered activated carbon, illustrating its large surface area, are shown in Figure 3.⁷

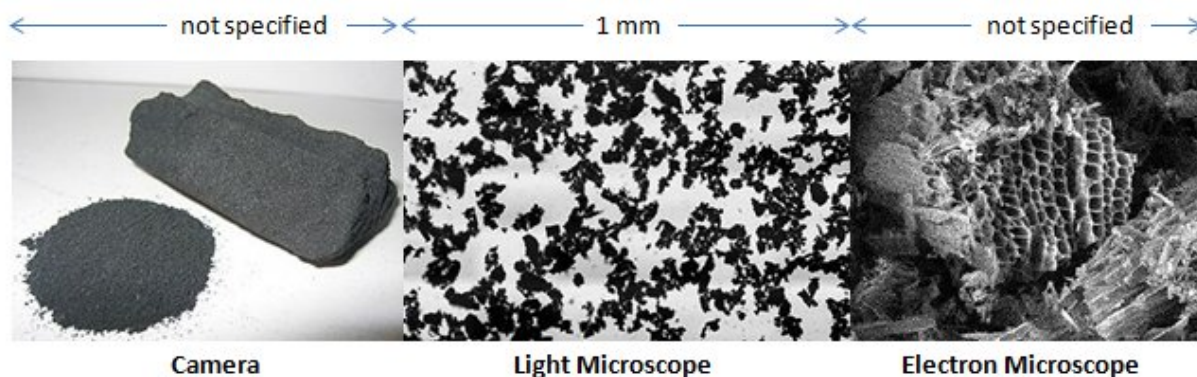


Figure 3 Photos of Activated Carbon at Different Scales

Lists of compounds for which activated carbon has been used successfully are given in the following page.⁸ They are presented to show the versatility of activated carbon for removing contaminants in water.

In the process, activated carbon is contained in a “bed” through which contaminated water is passed, as shown in Figure 4. In the bed, adsorption takes place which removes contaminants from the water. In this case, it is used only for “polishing”, in case there are still residual contaminants after the aeration and ozonation processes have been completed.

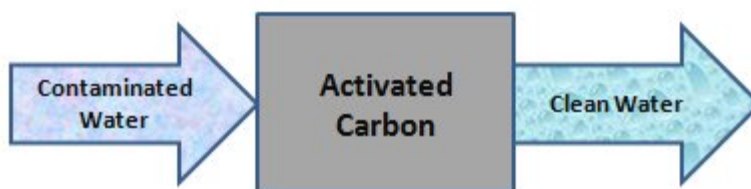


Figure 4. Water Decontamination with Activated Carbon

⁷ http://en.wikipedia.org/wiki/Activated_carbon

⁸ <http://www.lenntech.com/library/adsorption/adsorption.htm>

1.- Chemicals with **very high probability** of being adsorbed by active carbon:

2,4-D	Deisopropylatrazine	Linuron
Alachlor	Desethylatrazine	Malathion
Aldrin	Demeton-O	MCPA
Anthracene	Di-n-butylphthalate	Mecoprop
Atrazine	1,2-Dichlorobenzene	Metazachlor
Azinphos-ethyl	1,3-Dichlorobenzene	2-Methyl benzenamine
Bentazone	1,4-Dichlorobenzene	Methyl naphthalene
Biphenil	2,4-Dichlorocresol	2-Methylbutane
2,2-Bipyridine	2,5-Dichlorophenol	Monuron
Bis(2-Ethylhexyl)Phthalate	3,6-Dichlorophenol	Napthalene
Bromacil	2,4-Dichlorophenoxy	Nitrobenzene
Bromodichloromethane	Dieldrin	m-Nitrophenol
p-Bromophenol	Diethylphthalate	o-Nitrophenol
Butylbenzene	2,4-Dinitrocresol	p-Nitrophenol
Calcium Hypochloryte	2,4-Dinitrotoluene	Ozone
Carbofuran	2,6-Dinitrotoluene	Parathion
Chlorine	Diuron	Pentachlorophenol
Chlorine dioxide	Endosulfan	Propazine
Chlorobenzene	Endrin	Simazine
4-Chloro-2-nitrotoluene	Ethylbenzene	Terbutryn
2-Chlorophenol	Hezachlorobenzene	Tetrachloroethylene
Chlorotoluene	Hezachlorobutadiene	Triclopyr
Chrysene	Hexane	1,3,5-Trimethylbenzene
m-Cresol	Isodrin	m-Xylene
Cyanazine	Isooctane	o-Xylene
Cyclohexane	Isoproturon	p-Xylene
DDT	Lindane	2,4-Xylenol

2.- Chemicals with **high probability** of being adsorbed by active carbon:

Aniline	Dibromo-3-chloropropane	1-Pentanol
Benzene	Dibromochloromethane	Phenol
Benzyl alcohol	1,1-Dichloroethylene	Phenylalanine
Benzoic acid	cis-1,2- Dichloroethylene	o-Phthalic acid
Bis(2-chloroethyl) ether	trans-1,2- Dichloroethylene	Styrene
Bromodichloromethane	1,2-Dichloropropane	1,1,2,2-Tetrachloroethane
Bromoform	Ethylene	Toluene
Carbon tetrachloride	Hydroquinone	1,1,1-Trichloroethane
1-Chloropropane	Methyl Isobutyl Ketone	Trichloroethylene
Chlorotoluron	4-Methylbenzenamine	Vinyl acetate