Name of Process:
Solvated Electron Technology (SET ™)

Vendor:
Commodore Applied Technologies, Inc.
Web site: http://www.commodore.com/

Applicable Pesticides and related POPs wastes:
Wide range of POPs and other chemicals in soil, including PCBs (transformers, capacitors, liquids), DDT, HCB, malathion, mixed organochlorine pesticides, dioxin/furan and explosives contaminated soils.

Status:
The SET ™ process operates works at commercial scale [10] and has been working many years at Pilot/Demonstration scale in USA and has treated a wide range of POPs and other chemicals in soil.

In August 1995, Commodore's SET™ technology was demonstrated to the U.S. Environmental Protection Agency (EPA) and in March 1996, the EPA issued a nationwide permit allowing Commodore to use SET™ on-site to treat PCB-contaminated soil at any location in the United States. In addition to soil treatment, the nationwide permit allows Commodore to treat PCB-contaminated metallic surfaces. The permit was amended in May 1998 to include the treatment of oils [1].

Recognized by EPA as a non-thermal process equivalent to incineration, SET™ is believed to be the only multi-matrix PCB chemical destruction process approved for nationwide operation [1].

Technology description:
The Solvated Electron Technology (SET ™) is a patented non-thermal process for the treatment of a wide range of organics. The SET ™ process uses solvated electron solutions to reduce organic compounds to metal salts and the parent (de-halogenated) molecule. Solvated electron solutions, which are strong reducing agents, are formed by dissolving alkali or alkaline earth metals such as sodium or calcium in anhydrous liquid ammonia. Example byproducts from treating PCB-contaminated waste include petroleum hydrocarbons, sodium chloride, and sodium amide [2].

Basic Chemistry

The process uses alkali or alkaline earth metals such as sodium, calcium, lithium, etc dissolved in any of a variety of solvents including ammonia, amines, and some ethers to produce a solution of free electrons and metal cations.

For example, in NH3, Na -----> Na+ + e-

Dehalogenation reaction pathways vary depending on the halogenated compound present, but can be illustrated by the following generic reaction:

RX + 2M + H2O -------> RH + MX + MOH

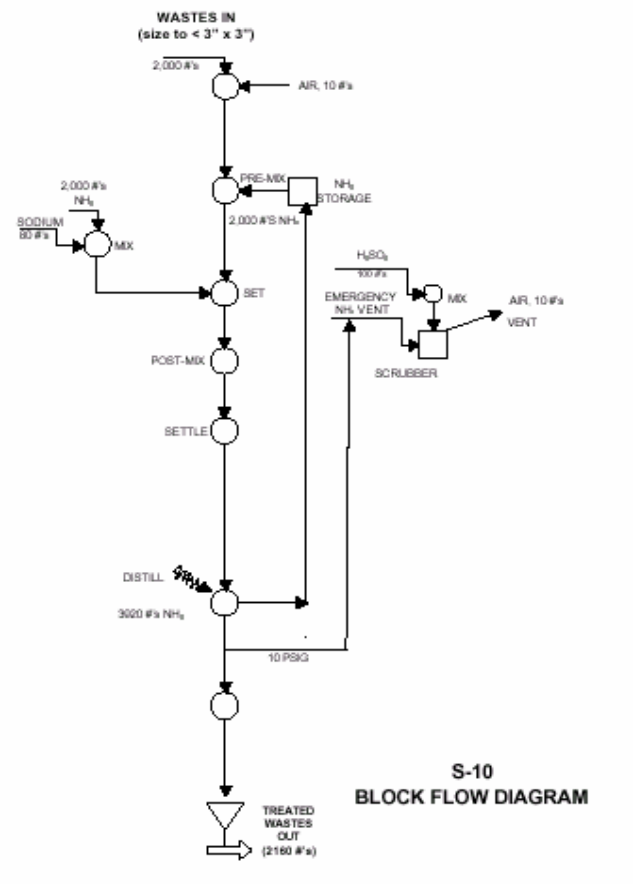
The deleterious effects of water, iron and its compounds, oxygen, and carbon dioxide on solvated electron solutions are well known. However, a major breakthrough by Commodore has provided a mechanism for treating toxins and contaminated matrices, even when substantial quantities of water and/or other competing reactants are present in the matrix to be treated.

Halogenated organic compounds are "destroyed" by Commodore's SET process when halogens are selectively stripped from the parent hydrocarbon by the free electrons (dehalogenation) and captured by the metal cations to form salts (such as calcium chloride) and hydrogen-substituted organic compounds (such as saturated hydrocarbons in the case of PCBs). The process occurs at room temperature and is essentially instantaneous. [4]

Process Desciption

The SoLV™ process is modular in nature. Commodore has developed several process variations depending on the nature of the material being remediated. The various modules are designed to be tailored to each particular remediation site in a manner such that the most cost-effective sequence is utilized. The SET™ treatment module is the centerpiece of the process and is a critical component of each process. All equipment is mobile and able to be placed at the site, which eliminates the expense of transporting hazardous materials. Space does not allow the description of all the possible combinations of these modules. However, they generally include front-end modules that can remove water or extract the contaminants of interest. Next, the SET™ treatment module is required to destroy the contaminants. Back end modules are available to recycle ammonia, pH adjust, concentrate or fix the reaction products depending on the specific needs of the client [3].

Process diagram [10]**:**



Treatment efficiency:

The SoLV™ process can be modified to deliver the targeted remediation level. Soils containing many different organic contaminates have been treated. These include PCBs, PAHs, chlorinated solvents, dioxins, furans, pesticides, hexachlorobenzene, BTXs, volatiles, and semi-volatiles. After treatment with the SoLV™ process, treated soils pass all TCLP criteria for replacement or non-hazardous waste landfill disposal. The following Table contains data from several projects. Small quantities of soil are treated in the S/4 treatment unit while larger quantities are treated in the S-10 [3].

Destruction of PCBs in Various Soils

Source of Soil	Soil Type	Pre-Treatment (ppm)	Post-Treatment (ppm)
Harrisburg, PA	Sand, clay	777	<1.0
Los Alamos, NM	Sand, silt, clay	77	<2.0
New York	Sand, silt	1250	<2.0
Monroe, LA	Sand, silt, clay	8.8	<1.0

Oils [3]
Oils such as contaminated transformer and cutting fluids can be readily detoxified using SET™ in Commodore's L-1200 system. This is a liquid unit, which requires the ability to pump the material to be treated. Oils containing over 20,000 ppm of PCB have been detoxified to below 0.5 ppm PCB. The next Table lists data for destruction of PCBs in oils.

Destruction of PCBs in Oils

Material	Pre-Treatment (ppm)	Post-treatment (ppm)
Used Motor oil	23,339	<1.0
Transformer oil	509,000	20*
Mineral Oil	5000	<0.5
Hexane	100,000	0.5

*Sodium feed was deficient. Can be improved by using additional sodium.

Commodore further performed treatability study of PCB-contaminated soils from a transformer spill at a Pennsylvania Air National Guard site demonstrating destruction efficiencies of over 99%. Commodore Advanced Sciences is contracted to treat over 170 tons of PCB contaminated soil in 2000 [1].

Treated over 300 tons of PCB-contaminated soils excavated from an oil-spill site at the Pennsylvania Air National Guard base, located at the Harrisburg International Airport, utilizing the full-scale S-10 system to reduce PCB levels to <1ppm. During the treatment process, Commodore successfully performed an EPA demonstration of the commercial system [1].

PCBs/ Dioxins [3]

Commodore has completed numerous treatability studies in house and on site. Only a couple will be discussed herein.

The following Table gives data from a clean up of soil from a site in New York State. The soil contained approximately 1200 ppm of PCB (Aroclor 1254) prior to treatment with SET. After treatment the PCB level was reduced to 1.4 ppm. Small quantities of PAHs (pyrene, phenanthrene) were also remediated.

SET™ Treatment of Oil Spill New York State Utility Site

Contaminant	Pre-Treatment (ppm)	Post-Treatment (ppm)
Aroclor 1254	1200	1.4
Mercury	0.21	0.08
Lead	433	267
Pyrene	1.8	ND
Phenanthrene	1.4	ND

A New Bedford Harbor Massachusetts Sawyer Street site has been designated a superfund site due to PCB contamination. Commodore was one of three companies chosen to conduct demonstration studies on site under contract to Foster Wheeler Environmental Company. The river sediment was first washed with diisopropylamine by the Ionics RCC B.E.S.T ™ process producing an oil concentrate. The PCB level in the B.E.S.T concentrate was approximately 32,800 ppm. Dioxins /furans (TEFs) were also present at 47,000 ppt. This concentrate was reacted with SET™ in the SoLV™ process to destroy the PCB and dioxins. The results are given in the next Table. After treatment the material was found to have PCBs at a level of 1.3 ppm, well below regulatory requirements for disposal in non-hazardous waste landfills. Dioxins were also readily remediated.

SET™ Treatment of Sludge New Bedford Harbor

Contaminant	Pre-Treatment (ppm)	Post-Treatment (ppm)
PCB	32,800	1.3
Dioxin/Furan	47	.012
Mercury	0.93	.02
Lead	73	0.2
Selenium	2.5	0.2
Arsenic	2.8	0.1

The SET™ process can also be used to remediate dioxins when PCBs are not present. Waste oil from the McCormick and Baxter site in California was readily treated to ppt levels as illustrated in this Table.

SET™ Treatment of Dioxins in Waste Oil, McCormick and Baxter site, Stockton, CA

Contaminant	Pre-Treatment (ppt)	Post-Treatment (ppt)
Dioxins	418,500	2.3
Furans	14,120	1.3

Hexachlorobenzene [3]

SET™ is very effective in destruction of hexachlorobenzene in soils. Sandy soil containing 67.6 ppm of hexachlorobenzene was treated in the CMDU on site at Las Vegas, Nevada with a SET solution containing approximately 4 % by weight of sodium. The treated sandy soil was found to contain <2 ppm of hexachlorobenzene. GC/MS analysis of the treated soil established that no chlorinated species were detected in the soil.

The SET™ process can also be used to remediate dioxins when PCBs are not present. Here 100 pounds of soil was treated [10]. Waste oil from the McCormick and Baxter site in California was readily treated to ppt levels as illustrated in this Table.

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Bulk Pesticides [3]

Destruction of bulk pesticides has been carried out in Commodore's Marengo Ohio facility using malathion. This work was conducted in Commodore's L1200 liquid unit in 100 pound quantities. Near stoichiometric quantities of sodium were required to destroy the malathion. The levels of malathion in the treated material were at non-detect. Most bulk organic pesticides and herbicides containing halogens, phosphorous, or sulfur are amenable to reductive destruction using the SET process. Many waste streams produced when manufacturing pesticides can be remediated using SET™.

Pesticides in Soils [3]

In addition to PCBs, other organics in soils, such as pesticides can be remediated. The next Table gives data from a project where soils from Hawaii and Virginia were contaminated with DDT, DDD, DDE, and dieldrin. In all cases, the soils were remediated to non-detect levels of the respective pesticide. These runs were conducted on site at Port Hueneme, California Naval Station using Commodore's mobile demonstration unit (CMDU). Soils were shipped in from other naval facilities.

Destruction of Pesticides in Soil with SET™

	DDD	DDT	DDE	Dieldrin
Barbers Point, HI				
Pre-treatment	200	180	69	ND
Post-treatment	<.02	<.02	<.02	ND
Dahlgren, VA				
Pre-treatment	9	1.6	ND	15
Post-treatment	<.02	<.02	ND	<.02

Explosives [3]

Soil collected form Los Alamos, New Mexico, contaminated with RDX, HMX, and 1,2 DNB, has been remediated using SET. After treatment, no detectable level of explosive was noted. This Table contains data from this soil.

Destruction of Explosives in Soil, from Los Alamos, New Mexico

	HMX	RDX	1,2 DNB
Not Treated (mg/kg)	1600	3580	9.6
Treated (mg/kg)	.03	.03	.03
Detection Limit	.03	.03	.03
Destruction Efficiency (%)	99.9999	99.99999	99.99

Chemical Warfare Agents [3]

Over 300 tests have been conducted by Commodore on all stockpiled agents (GA, GB, GD, GF, Lewisite, VX, HD, HT, T, HN-1, HN-3, HL, picric acid, CG, and CK). Destruction efficiencies of greater than 99.9999 % have consistently been attained. As part of the army ACWA program, reaction products have been extensively characterized. They have also been tested for acute toxicity and found to be CLASS 1 or Class 0 level.

Within the framework of ACWA programme, Teledyne-Commodore's Solvated Electron Technology (SET ™) was to test all seven primary components of their total solution. The demonstrations were to be conducted at DPG in Dugways, Urtah and at Deseret Chemical Depot (DCD) a t the chemical Agent Munitions Disposal Systems (SAMDS) in Tooele, Utah.

However agent testing could not be completed and some of the conclusions are as follows [6]:

The lack of any data for agent or energetics from the ACWA demonstration prohibits the validation of the SET technology. Extensive laboratory and bench scale testing of the SET with agents HD, HT, GB and VX indicates that destruction efficiencies greater than 99.9999% can be achieved routinely [7]. Laboratory testing of SET with energetics (TNT, RSX, tetryl, M28 propellant, and Comp B) [8] as well limited chemical analyses from the SET-Energetics workup runs indicate that destruction efficiencies greater than 99.999% can be achieved routinely for all energetics except NG; the highest DRE for NG was 99.996%.

In summary, no information regarding the effectiveness of SET was collected during the ACWA Demonstration Test Program. Although prior small-scale laboratory testing by the technology provider indicates the likely effectiveness with agent and energetics, agents and energetics destruction have not been independently verified and validated in demonstration testing.

Radioactive Waste [1]

Currently treating 20,500 lbs. of mixed radioactive and hazardous solvent wastes for a contract with American Ecology Recycle Center, Inc. (AERC), at facilities in Oak Ridge, Tennessee. The SL-2 SET system is treating hazardous residues generated during the cleanup of radioactively contaminated tools, equipment, and other metallic materials.

Using the company's proprietary SET™ process, Commodore has treated 60,000 pounds of radioactive mixed waste.

Throughput:
SET™ is *scalable* and can accommodate the size of the project. Commodore's units can be efficiently and effectively scaled to treat any amount of waste, no matter how large or small [1].

Commodore's commercial L1200 liquid unit applicable to materials like PCBs in oil, liquid pesticides or extracted contaminates. Commodore's L1200 liquid unit in 100 pound quantities [3].

Larger quantities are treated in the S-10 with 10 ton per day [3].

Commodore also has a solids handling unit capable of treating drum quantities of solids or liquids. This treatment unit is Commodore's S/4 treatment vessel. Small quantities of soil are treated in the S/4 [3].

Wastes/Residuals:
The primary effluents of the SET™ process are non-hazardous inorganic sodium salts and hydrocarbons. Verified by the US Environmental Protection Agency, the halogenated organic (containing fluorine, iodine or chlorine) materials found in hazardous wastes do not survive the treatment process. Depending on the original waste agent, the residual waste products from the process can be disposed in a regulated landfill, returned to the environment, or event reused in another process [1]. After treatment with the SoLV™ process, treated soils pass all TCLP criteria for replacement or non-hazardous waste landfill disposal [3].

Reliability:
SET systems are constructed from commercial mixers, refrigeration systems, boilers, and other readily available equipment. This equipment is subject to routine maintenance as may be expected, and the SET systems are designed to operate at 80% capacity continually.

Limitations:
Any compound capable of chemical reduction, in such a form as can be wetted by ammonia, is a candidate for SET treatment. Water content above 40% by weight will require some form of drying. Size restrictions are currently 18" diameter for solid materials.

Detailed information:

Full Scale Treatment examples:
See Annex

Transportability:
All equipment is mobile and able to be placed at the site [3].

Conclusion:
The SET ™ process is a well-developed technology working now at commercial scale and has a proven record of practical demonstration and pilot scale experiences for pesticides and related POPs compounds. Commodore's S-10 is able to treat 10 ton per day. The company is claiming to work since 3 years at a commercial scale especially in the field of nuclear waste and PCB's and quotes that the market prices for the treatment of pesticides are just too low.

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**Note: This NATO/CCMS fellowship report does not certify any particular technology, but tries to summarise the state of the art of the concerned technology on the basis of data delivered by the company or other source, which have been made available to the author and refers the reader to original documents for further evaluation. Without the efforts of the Technology supplier it would not have been possible to set up this fact sheet.*
***** Note:The text for this report is verified by the Technology supplier on 12. December 2002*

References:

1. http://www.commodore.com/ (version between March and December 2002)

2. Commodore, October 1998

3. Solvated Electron Chemistry, A Versatile Alternative for Waste Detoxification, Dr. Gerry Getman
Vice President-Research and Development, Commodore Solution Technologies, Inc., 4500 Township Road TWP 161, Marengo, OH 43334, August 15, 1999

4. US EPA SITE PROGRAM, Vendor information

5. http://www.pmacwa.org/code/technology/teledyne.asp

6. Assembled Chemical Weapons Assessment Program, Supplemental Report to Congress, June 2001

7. Teledyne-Commodore, *Draft Demonstration test Technical Report*, 17 November 2000, pp. 4-42, 4-55, 4-64.

8. Ibid, pp. 4-45-4-45-4-48, 4-55-4-59, 4-64-4-65.

9. Ibid, pp. 3-80-3-88.

10. Written comments on Fact Sheet Mack Jones, Commodore, 12. December 2002

Patents [1]:				
4,968,393	11/06/90	Membrane Divided Aqueous-Nonaqueous System for Electrochemical Cells	Dehalogenation by electrochemistry using divided aqueous/nonaqueous cells	
5,110,364	05/05/92	Processes for Decontaminating Polluted Substrates	Treatment of soils, surfaces, oils, by solvated electron solutions	
5,414,200	5/09/95	Non-Metallized and Substoichiometric Metallized Reactions with Ammonia and Other Weak Bases in the Dehologenation of Refrigerants	CFC destruction by solvated electron and ammonia	
5,495,062	02/27/96	Methods of Decontaminating Nuclear waste-Containing Soil	Removal of radionuclides in soil	Israel, New Zealand
5,497,627	03/12/96	Methods for Purifying Refrigerant Compositions	Aqueous extraction of select refrigerants from mixes allowing recovery of the useful material	
5,516,968	05/14/96	Methods of Decontaminating Mercury-Containing Soils	Removal of mercury from soils	Australia, Israel, Japan, Pakistan, South Africa
5,559,278	09/24/96	Methods for the Destruction of Ozone Depleting Substances	CFC destruction by solvated electron and ammonia	Australia, New Zealand, Pakistan, South Africa
5,602,295	03/11/97	Methods for the Elimination of Cyanides in the Dehalogenation of Halofluorocarbons	CFC destruction	Australia
5,998,691	12/07/99	Method and Apparatus to Destroy Chem Warfare Agents	Chem DeMil applications	Iran, Turkey, South Africa, Pakistan, Eurasian, North Korea
5,613,238	03/18/97	Method of Decontaminating Soils Containing Hazardous Metals	Removal of heavy metals from soil	Israel, Japan, New Zealand, Pakistan, South Africa
5,616,821	04/01/97	Method for Purifying and Recovering Contaminated Refrigerants with Solutions of Bases in Organic Solvents	Selective refrigerant destructive refrigerant	Australia, Israel, Pakistan, South Africa
5,678,231	10/14/97	Method of Decontaminating Substrates with In-Situ Generated Cyanides	Removal of heavy and radioactive metals	

5,698,750	12/16/97	Method for Purifying Contaminated Refrigerants with Aqueous Solutions of Bases	Selective refrigerant destruction	
5,582,744	12/10/96	Pressurized Filtration	Apparatus for pressure filtration of a slurry mixture	
6,049,021	4/11/2000	Method for Remediation of sites Contaminated with Toxic Wastes		
6,121,506	9/19/2000	Method for Destroying Energetic Materials	Explosives/Pyrotechnics destruction applications	Pakistan, South Korea, Iran