The Theta Process
A Natural Solution for Acid Pollution

By

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Introduction

Pat Gallagher, a reclamation engineer form Columbus Test Laboratories in West Virginia, was hired by General refractories to use hydrologic engineering to handle an acid mine drain problem on a worked-out clay mine site in Somerset, Pennsylvania. They sealed about 95% of seeps from the abandoned deep and strip sites. Clarence Beach, he caretaker of the property and reclamation man at the Fort Hill site, had leveled, graded and planted the sites. Together, they had a lime plant that dropped out the hydroxide metal forms and got the pH up to 6 at the discharge point. But, the sludge pits were filled to overflowing and three major seeps were draining AMDW to create Little Red Lake and Big Red Lake. There seemed to be no way t stop it; 5,000,000 gallons of AMDW, more seeping out of three sites, and no more sludge pits in which store it.

The problem is a well-known one: is the effect on aquatic ecosystems of acidic effluent – AMDW, industrial effluent, or acid deposition ("acid rain"). Lambda Group's Theta process is the solution to the problem. *Theta* stands for death; its delivery system, Immobilized Microbial Pollution Purification Systems (IMPPS), can prevent the "death" of aquatic ecosystems. The microorganisms can live in ecological balance in a pH range of 0.5 to 5.0 and chelate and oxidize free ions. I have developed a nutrient matrix of a colloidal nature that provides food, a free flow of gases and water through the IMPPS for greater concentration and faster reaction time. The Theta process is a mixotrophic, synergistic, symbiotic, microbial ecosystem capable of chelating and oxidizing sulfur and heavy metals into an oxide of the metals and sulfur which are non-toxic to aquatic life. These oxides are normally found in soil and aquatic bottoms as part of the sulfur cycle, iron cycle aluminum cycle, etc. When acidified, they lose the oxygen and become toxic ions, such as aluminum which kills plants, trees, crayfish, and trout.

The literature is replete with numerous explanations of cause and effect; I have attached a bibliography.

Methods and Materials

The ancient, shallow Teays River covered the Eastern United States and Canada until the last Ice Age. The recession of the glacier literally dug the Great Lakes, which were filled by the

North-flowing Teays River. I have studied the remnant bags, swamps, and marshes for fourteen years and found:

1. 78% were in or near coal or other minable materials areas.
2. The ones that were not were alkaline bogs or in the northeastern Ohio area around Lake Erie. Even some of these were in or near natural gas wells.
3. From the tundra (cold desert bogs) to the Appalachian acid bogs, swamps, and marshes, there was a commonality of microbial species.

From water and plan samples, microorganisms were cultured out (most were medium-specific). These were the wild microorganisms used in the process. Pure cultures of bacteria were ordered from The American Type Culture Collection, and algae and protozoa from the Texas Algae Depository, Carolina Biologicals, and Nasco Biologicals. These cultures were used to correctly identify the wild microorganisms.

A nutrient medium was developed in which all the microorganisms could live, grow, and reproduce. Two drops from the wild and two from the pure strains of microorganisms were transferred into 10ml of the IMPPS medium after it was developed. They formed a vigorous hybrid that stayed in the stationary phase (when enzyme production is at its peak) longer than the wild or the tame cultures alone.

Results

There were now three generations or applications of the Theta process. The first generation, TP-1, using only mixotrophic microorganisms in a ecologically balanced synergistic, symbiotic system, is effective in cleaning up AMDW. The transparency shows that the point at which pH and redox met, the maximum amount of iron and sulfur has been removed. The results were as projected, but the time frame of 130 – 180 days was much too slow.

TP-2, or second generation, used only the bacterial enzymes embedded in Manville R-630 celite catalytic carriers. One advantage of this was the reusability of the enzyme-filled carriers. The same results as before were achieved: sulfur and iron were gone when redox and pH matched. But the time span was reduced to 10-14 days.

TP-3, or third generation, did everything the previous two generations did, only better and faster. Within four hours or less, substantial sulfur and iron were removed.

They key is the ability of the Theta IMPPS to concentrate the organisms at the point source of pollution and the ability of the microorganisms to double heir populations within a two-day period, thereby maintaining all the organisms at the maximum carrying capacity of that system.

The Chart #1 transparency shows the ability of the IMPPS to continue cleaning once they are established in an aquatic system. In the chelation/oxidation process, the bacterial catalytic enzymes are necessary for chelation/oxidation to occur, but are not used up by the process, nor are the organisms (the IMPPS) used up by the process, since they do not "eat" or inject the sulfur, iron, etc. They use them only as energy substrates.

Static

		pH	MV	Fe	SO4
#1	start	3.3	409	10	250
	end	3.2	418	0	0
#2	start	3.3	409	0	250
	end	3.4	410	0	3
#3	start	3.3	409	0	250
	end	3.17	428	1	0
#4	start	3.3	409	10	250
	end	3.35	420	0	2
#5	start	3.3	400	10	250
	end	3.6	368	1	0
#6	start	3.3	409	10	250
	end	3.3	382	1	0
#7	start	3.3	409	10	200
	end	3.3	388	0	2
#8	start	3.3	409	10	250
	end	3.25	400	0	50
#9	start	3.3	409	10	250
	end	3.2	418	0	30

Aerated

		pH	MV	Fe	SO4
#1	start	3.3	409	10	250
	end	3.4	410	0	3
#2	start	3.3	409	10	250
	end	3.4	410	0	3
#3	start	3.3	409	10	250
	end	3.71	410	0	1
#4	start	3.3	409	10	250
	end	3.56	420	0	50
#5	start	3.3	409	10	250
	end	3.5	363	3	100
#6	start	3.3	409	10	250
	end	3.5	363	3	100
#7	start	3.3	409	10	250
	end	3.6	430	2	0
#8	start	3.3	409	10	250
	end	3.7	381	1	0
#9	start	3.3	409	10	250
	end	3.65	407	3	0

STATIC

		pH	MV	Fe	SO4
#1	start	3.3	409	10	250
	end	3.2	418	0	0
#2	start	3.3	409	0	250
	end	3.4	410	0	3
#3	start	3.3	409	10	250
	end	3.17	428	1	0
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	end	3.35	420	0	2
#5	start	3.3	400	10	250
	end	3.6	368	1	0
#6	start	3.3	409	10	250
	end	3.3	382	1	0
#7	start	3.3	409	10	200
	end	3.3	388	0	2
#8	start	3.3	409	10	250
	end	3.25	400	0	50
#9	start	3.3	409	10	250
	end	3.2	418	0	30

AERATED

		pH	MV	Fe	SO4
#1	start	3.3	409	10	250
	end	3.4	410	0	3
#2	start	3.3	409	10	250
	end	3.4	410	0	3
#3	start	3.3	409	10	250
	end	3.71	410	0	1
#4	start	3.3	409	10	250
	end	3.56	420	0	50
#5	start	3.3	409	10	250
	end	3.5	363	3	100
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	end	3.6	430	2	0
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	end	3.7	381	1	0
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	end	3.65	407	3	0

A Horizon Ecological Systems bio-oxidation reactor with probes and a three-pen strip chart recorder has made it possible to plot pH, redox, and dissolved oxygen through two- to three- week cycles. We used soil and water from the Fort Hill site Lambda is cleaning in Pennsylvania, and added the hybrid microorganisms in their IMPP carriers were added. The Hypothesis shown on the chart #3 transparency was verified.

1. The chelation/oxidation rate reacted to and oxidized the sulfur, iron, manganese, and aluminum each time additional AMDW was added to the system. We ran it for fourteen days, adding more highly concentrated AMDW each day (approximately 200ml daily).
2. While the chelated oxides dropped to the bottom in the soil sediment, the normal sulfur, iron, manganese, aluminum, etc., cycles were speeded up, especially when the pieces of the IMPPS matrix fell into the sediment. Like hermit crabs in the oceans, the soil bacteria collected in the IMPPS and indicated a much faster reaction time than the same soil without IMPPS. Transparencies #3 and #4 show examples of the cycles that were enhanced with the IMPPS.
3. The green algae and Mastigophora formed a green mat-like surface on top of the soil, starting as pioneer plants in the succession process necessary to bring the aquatic system and its surrounding ecotone back to their historically natural states (determined from the Somerset County, Pennsylvania, Soil conservation Book).
4. With the Mixture of the organisms from the fort Hill mine site, and our tame and wild organism, we custom-created as hybrids that grew bigger, lived longer, and gave off more enzymes.
5. A four- to eight-hour retention time was needed where the pollutants and the IMPPS were accessible to each other in reduce the manganese, iron, sulfate, and aluminum required to meet Pennsylvania state regulations.
6. The pH would not go beyond 4.83 because 4.83 was and is the natural pH of the soil and water in Somerset, Pennsylvania. The state requires a 6-9 pH, necessitating a final run of the cleaned water over a 100-foot limestone bed to bolster the pH to 6-9 at the discharge point.

Transparency #5 shows the basic ecosystem concept. #6 shows the negative feedback system that maintains the populations at carrying capacity.

The scale-up to 200 gallons of IMPPS has provided invaluable data: (1) the IMPPS do scale up; (2) they do not lose their efficiency; (3) the process is not expensive; and (4) once the IMPPS are in place, they continue working.

Transparency #7 shows the engineering of the Fort Hill site for the Theta IMPPS demonstration.

CONCLUSIONS

The theta process has application potential for AMDW, industrial effluent, and aquatic systems destroyed by acid rain, snow, and fog. It is harmless because it is made of natural materials and organisms indigenous to the area. The IMPPS can be custom-made for each job.

The final results from Fort Hill will tell us if it is , as we strongly now believe, a one-shot proposition. Once the IMPPS are established, they will continue cleaning.

Twenty to fifty gallons per day can be made in the lab, but doing it by had is expensive. Mass production is possible and the cost will drop once the manufacturing is started.

ACKNOWLEDGMENT

I would like to thank Pat Gallagher for recommending Lambda to General Refractories, and Glenn Jones, the General Refractories Project Director, for providing Lambda's first test site. Both General Refractories and Columbus Technical Laboratories tried a process never before used outside the laboratory.

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BENCH TEST DATA ON THETA PROCESS

	START				END			
	pH	Fe(ppm)	So4(ppm)	Al(ppm)	pH	Fe(ppm)	So4(ppm)	Al(ppm)
Milburn Refuse Area #1 W.V.	1.95	1,100	150,000	10	6.72	10	15	0
Milburn Refuse Area #2 W.V.	2.01	1,500	120,00	10	5.97	5	12	0
Upper Peninsula of Michigan	2.76	850	10,000	2	7.35	0	2	0
S.E. Ohio Sedimentation Pond	2.0	975	130,000	3	5.8	7	3	0
ODNR Site Water	2.17	1,050	11,000	7	6.32	3	7	0

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August 26, 1985

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Date Received: August 1, 1985

ANALYTICAL REPORT

Sample Lab No.	MRA1 Face Ditch 12-03	MRA2 ✓ French Drain 12-04	MRA2 ✓ After Treatment 12-05
pH	2.0	2.0	9.2
Total Hot Acidity mg/L $CaCO_3$	7,847	12,851	< 1
Mineral Acidity mg/L $CaCO_3$	5,694	7,381	< 1
Total Alkalinity mg/L $CaCO_3$	< 1	< 1	16,180
Total Fe ppm	2,100	9,200	0.6
Total Mn ppm	50	77	12
Total Cu ppm	.25	0.29	0.07
Al ppm	449	653	0.05
SO_4 ppm	5,170	11,500	450
TSS%	< 0.005	< 0.005	2.650
TDS%	1.441	2.65	4.61
Spec. Cond. u hmos	160,000	120,000	14,000

All analytical methods used are EPA accepted and/or EPA approved.

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8/25/85