Flocculation of Construction Site Runoff in Oregon

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Runoff Characteristics

Construction site runoff consists of sediment, suspended solids, colloidal suspensions, and dissolved metals. Oil and grease can also be found depending on the site activities. Sediment and suspended solids can readily be controlled and minimized through the use of standard Best Management Practices such as; silt fences, biobags, sediment ponds, straw bales, and etc. If maintenance of the BMPs is lacking or if care is not used when removing these BMPs after the site is finished with construction then the retained pollutants will still be released into the environment. There is some evidence to suggest that these BMPs may actually increase the amount of colloidal suspension in the runoff over that of bare ground.

Colloidal suspensions are typically measured as turbidity or as total dissolved solids. Colloidal particles are often less than 0.001 mm in diameter and carry a negative surface charge. These particles essentially never drop out of the liquid without some outside influence. The department has a sample taken from a pond that was over forty feet deep and had not had operation occurring including more runoff to disturb the waters other than wind and rain falling directly on the pond for at least three years. The sample measured over 2,000 N.T.U. turbidity with a total dissolved solids level of 7,120 mg/l.

One explanation for the particles staying suspended could be that like charges repel each other and the earth itself can be considered to be negatively charged which would also tend to repel the particles.

Concerns

The reasons that suspended particles are so important to the welfare of salmonid is that research indicates that turbid waters tend to have reduced levels of dissolved oxygen resulting from the reduced photosynthesis from plants due to lower light levels making it more difficult for salmonid to breath, aquatic insects and other food sources disappear, water temperature increases, and gill flutter and diseases are more prevalent in the fish. Many pollutants transport through soil attachment in runoff resulting in ingestion by fish and other wildlife and causing toxin accumulation in fish tissues.

Fish studies on salmonid in the northwest have shown that the impact of turbidity and suspended solids on aquatic life appears to depend on the duration and magnitude of exposure. The sensitivity of salmonid depends on the life stage. Older salmonid can survive high (200-20,000 mg/l) suspended solids concentrations for considerable periods. However, prolonged exposure to a turbidity level of 25 NTU can result in reduced growth (Sigler 1984). The effect of solids or turbidity on the early life stages of salmonid depends on the impact to the intergravel environment, intergravel dissolved oxygen, and the ability of juveniles to physically emerge from the gravels.

Newcombe and Jenson (1996) observed that the ill effects from sediment increase as a function of increasing particle size. The embryo and juvenile age classes appear to be more sensitive than adults, but empirical data is lacking especially for the youngest age classes of eggs through juvenile.

Sigler et al (1984) reports that younger, smaller fish (40 cm), grew less and were more likely to emigrate from laboratory raceway channels with moderately elevated turbidity levels (> 11 - 49 NTU **)** than were older, larger fish. This suggests that elevated turbidity soon after emergence would result in substantial emigration. In their study, turbidities as low as 25 NTUs caused a reduction in fish growth. Harvey (1989) identified displacement of juvenile salmonids at 50 NTU. Since juvenile anadromous salmonids do not easily migrate upstream, displacement downstream causes habitat loss. Scrivner et al (1993) observed that juvenile fish migrated from the Frazier river into a tributary where TSS was less than 25 mg/l to avoid higher sediment loads. Ptolemy (1993) observed reduced juvenile salmon density at a summer average of 21 NTU (61 mg/l TSS in their study) compared to clear streams. Gregory (1993) and Gregory and Northcoate (1993) suggest the juvenile Chinook salmon exhibit behavior consistent with both a reduced ability to see prey and a perceived reduced potential risk from predation due to increased turbidity as compared to very clear (1 NTU) conditions.

Servizi and Martins (1991) indicate that increased water temperature can decrease a fish's tolerance to suspended solids by effecting cough reflex, oxygen transfer rates, oxygen saturation levels, and metabolic rates. A fish's tolerance to suspended sediments may be related to its oxygen uptake ability and therefore to water temperatures.. Maximum tolerance of under-yearling coho measured as a 96 hour LC_{50} or LC_1 occurred near 7C with declining tolerance at higher temperatures. At 18C the 96 hour incipient lethal level (LC_1) of 2000 mg/l is only 25% of the 96-hour LC_1 of 8100 mg/l. Similarly, reduced tolerance near a 96 hour LC_1 of 2000 mg/l at low temperatures (< 2C). Juvenile small coho (< 0.52 g) were less tolerant than relatively larger fish. The LC_{50} and LC_1 of small Coho (< 0.52 g) was 35% of the larger fish. Tolerance to suspended solids is also temperature dependent for other fish species (Noggle 1978 in Servizi and Martins 1991).

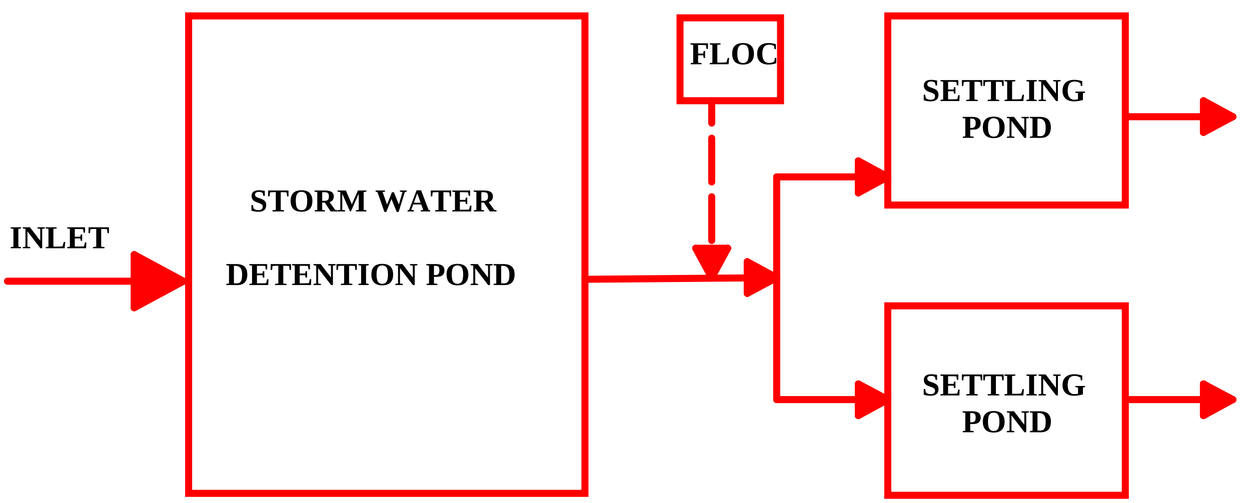
Suspended sediments impair primary production through light attenuation and increased abrasion of algae. Light penetration is reduced by turbidity. Light extinction is directly related to turbidity (Lloyd 1985). Studies in clear water streams in Alaska demonstrate that increased turbidity reduces primary production. Lloyd (1985) calculates that a turbidity of 5 NTU can reduce primary production in a normally shallow (1.5 feet) clear water stream by 13%; a 25 NTU increase in turbidity may reduce primary production by 50%. Jasper and Bothwell (1986) demonstrated that primary production was closely related to light presence history. Peterson (1985) showed that the biomass of invertebrates is related to primary production rates.

Flocculation

Flocculation is not a new process. It has been used for over 100 years to treat water. It has been used to treat wastewater in sewage and industrial treatment plants for many years. Recently, flocculation has been applied to storm water runoff to settle out the solids in the runoff. Some areas in Washington State have been using flocculation for the past couple of years to treat storm water runoff from construction sites.

Flocculation involves a three step process with possibly an additional step before or after relating to pH adjustment. A flocculant is a material which, in this case, is a positively charged (cationic) powder or viscous liquid. The flocculant is thoroughly but gently mixed with the liquid to be flocculated. In the first step, coagulation occurs. The positively charged flocculant attracts the negatively charged soil particle. As they come together they build into larger and larger particles until they start to settle out (floc). The settling of the particles is the clarification step. This can typically require up to 24 hours depending on the flocculant used, the dosage, the pH of the solution, the quality of the mixing, and the ability to minimize the settling pond or tank disturbance. When using flocculants, caution must be used to ensure that severe over-dosing does not occur. Over-dosing by too much may result in fish or other aquatic life toxicity and thus violate State Water Quality Standards.

Three tanks or ponds or combinations thereof are needed to perform flocculation. A fourth tank or pond may be used for mixing. The schematic below shows the general layout without the fourth tank or pond.



Oregon Sites

In 1999, two adjacent sites opted to try flocculation when all other attempts to control turbidity had failed to get the sites in compliance with the State Water Quality Standard. The sites were Summerlinn Apartments and West Linn Corporate Park. More data is available for the West Linn Corporate Park than for the Summerlinn Apartments site due mainly to West Linn Corporate Park being the first one to set up and operate a flocculation system. This is the system that will be discussed here.

Approximately 24.0 acres of land on slope with minimal overburden on bedrock drained to the Blankenship Road roadside ditch. This ditch then drained into a 48" diameter pipe drain that discharged the storm water into the I-205 roadside drainage ditch at the end of 13^{th} Street, where it terminated in a cul-de-sac next to the I-205 freeway. Sandbags in the end of the 48" diameter pipe prevented the turbid storm water from discharging into the roadside ditch. Two pumps in parallel picked up the storm water and delivered it to the first Frac tank for the addition and mixing of the flocculant. Sumalchlor 50, manufactured by Summit Research Labs, was the flocculant selected due to its relative ability to be pH insensitive and showed rapid settling in lab tests. Sumalchlor-50 is an inorganic coagulant with a short residence life in the water being treated and the aluminum compounds will quickly hydrolyze to form inert aluminum hydroxide. Toxicity tests provided by Summit Research Labs conducted on *Ceriodaphnia dubia* (daphnia shrimp) and fathead minnows found Sumalchlor-50 to have a 96-hour LC50 of 720 mg/L for fathead minnows and a 48 hour LC50 of 0.32 mg/L for daphnia shrimp.

A 1 year, 24 hour storm with a total rainfall of 1" was the design storm event for this system. A review of PDX rainfall data for March through June, 1992-1996, found that of the 610 days in these months, only twice was there more than 1" of rainfall in 24 hours. This storm generated a peak-anticipated flow of 1.28 cfs (575 gallons per minute) at the outfall of the 48" pipe. Utilization of the 48" pipe as a detention pipe allowed the peak pumping requirements to be approximately 300 gpm without overflowing the sandbags.

The first Frac tank was the place where coagulation and flocculation took place. The prescribed amount of the flocculant was injected and mixed the water for a set time in a 17,000-gallon Frac tank. This system was controlled by input volume and had the capacity to mix and treat approximately 500 gpm.

Pumps were used to evacuate the mixed storm water and distribute it to the settling tanks. The extraction system at 450 gpm was designed to exceed the input capability.

Two baffled 17,000-gallon Frac tanks, which received the water from the mixing tank were used for settling. These tanks allowed soil particles to settle and clean water to discharge via gravity from a four-inch outlet, located approximately four and one-half feet above the bottom of the tank. The discharge was piped into the adjoining stream. Discharge sampling was conducted at this point.

Sampling Results

Date	Intake NTU	Discharge 1 NTU	Discharge 2 NTU	Upgradient NTU	Batches per day	Batch Quantity (Liters)	Chemical Ratio (Liters/batch)
3/31/99	472.0	11.4	6.84	16.8	3.0	24,000	2.0
4/01/99	136.1	36.1	-	56.0	2.0	19,000	2.0
4/02/99	128.3	28.3	24.5	37.0	2.0	19,000	2.0
4/03/99	155.3	25.8	23.4	55.0	3.5	24,000	2.0
4/06/99	128.0	9.8	22.4	20.0	1.5	19,000	2.0
4/08/99	167.12	19.5	19.87	36.5	3.0	24,000	2.0
4/13/99	361.0	5.1	4.6	24.9	No Flow	-	-
5/03/99	124.6	34.4	No Flow	31.7	1.0	19,000	2.0
6/08/99	78.1	4.9	1.0	22.7	No Flow	-	-

Note: Between 3-1 and 3-25-99 monitoring was for System Development purposes and is not used for system evaluation. Chemical Ratio ranged from .5 liters per batch to 7.57 liters per batch. Batches ranged from 19,000 liters to 30,000 liters.

Note: Chemical Ratio increases to 3.0 Liters per batch on 5-17-99 due to increased turbidity onsite.

Aluminum & Chloride Results (mg/L)

Turbidity Results given in NTU (National Turbidity Units)

Date	Turbidity	Aluminum	Chloride
3/08/99	-	0.927	21.4
3/11/99	90.0	-	-
4/01/99	19.0	1.95	11.2

Discharge from the settling tanks was piped to the I-205 roadside ditch. The ditch crosses beneath the adjoining Interstate 205 freeway approximately 40 feet downstream of the discharge point and meanders southeast for approximately 5,600 feet to where it spills into the Willamette River. The drainage basin above this treatment system was approximately 24.0 acres. The drainage basin above the freeway crossing is 43.7 acres and the basin size above the outfall into the Willamette River is 572.3 acres. Discharge from this treatment system was immediately diluted as it was discharged to the ditch and continued to dilute further as it progressed downstream.

As needed, the settling tank was pumped with a vacuum truck, and the remaining soil was removed for onsite landscaping use.

Five minnows captured from the roadside ditch live in bucket of flocculation tank discharge for seven days.

The following is a summary of projected costs to construct, monitor and dismantle the three tank Stormwater Flocculation System.

Initial System Setup	$1,000.00-1,500.00
Weekly Monitoring, Testing, and Equipment Rental	$2,000.00
Chemical Costs **per 1000 Gallons**	$ .30
Settling Tank Cleaning (utilizing vacuum truck and onsite disposal) **per event**	$500.00
System Dismantling	$1,000.00

In 2000, another similar system was installed on the Hoodview Estates site off SW Salamo Road in West Linn. This system used only a single tank for adding and mixing the flocculant. The underground water quality detention tank was used for upstream detention and a pond was used for settling after the tank. The discharge from the pond was to a stream, which discharged into Tanner Creek.

Below is the data available at this time for the 2000 site.

Date	Location	Temperature	Turbidity in N.T.U.	pH
1/14/2000	Inlet	54	696.0	8.1
	Discharge	56	25.2	7.5
	Stream Background	55	25.2	6.9
2/02/2000	Inlet	54	650.0	7.9
	Discharge	55	25.0	7.4
	Stream Background	53	24.1	6.8
2/09/2000	Inlet	56	466.0	7.2
	Discharge	55	13.95	7.4
	Stream Background	52	9.38	7.8

Conclusions

Flocculation works and works very well. Cost data in Oregon indicates that the cost to Flocculate storm water runoff is around $ 0.08 per gallon of water treated. This is high mainly due to the high rental costs of the equipment and the consultant time involved. It is believed that these costs could be lowered substantially through more use of ponds instead of tanks and with a reduction of consultant time as more experience is gained. The flocculation efforts in Washington State indicate that the costs by using ponds only is between ½ % and 1.5 % of the site development costs. In Washington State, developers and contractors have indicated that they would prefer to floc than to attempt to control runoff by conventional BMPs. By reducing or eliminating the conventional BMPs a large portion of the floc costs can be offset. Contractors believed that flocculation was more reliable and less frustrating to use than conventional BMPs and stated that conventional BMPs, no matter what they tried to make work effectively, allowed turbid runoff to leave their sites. Washington State projects also showed a reduction in total phosphorus by a minimum of 95 %.

References

Polymer-Assisted Clarification of Stormwater from Construction Sites, Feb. 8, 1999, J. Resource Planning Associates, HoweConsult – contact Gary Minton at themintons@compuserve.com

Flocculation System Summary for the West Linn Corporate Park, Sept. 30, 1999, Patrick A. Sisul, P.E., Sisul Engineering, (503) 657-0188, J. Craig Spainhower, President, CJE Consultants and Constructers, Inc. (503) 743-2291 – cje@viser.net

Robert A. Funk, P.E., OCT Inc., flocculation consultant, (503) 650-8735

Hoodview Estates Stormwater Treatment System, Feb. 15, 2000, J. Craig Spainhower, President, CJE Consultants and Constructers, Inc. (503) 743-2291 – cje@viser.net

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