NUTRIENT REMOVAL USING COANDA SCREENS

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INTRODUCTION

Tilted wedgewire Coanda Screens have been used for decades in the hydropower and agricultural industries. Their small openings, typically 0.5 to 1.0 mm, have gained increasing favor for use in removing urban trash and gross solids. The efficacy of the Coanda Screens in treating storm water has been confirmed by third party testing agencies, including one Federal agency which concluded: "These screens have large flow capacities and are hydraulically self-cleaning without moving parts, so they require minimal maintenance."[1]

The authors have pioneered the use of Coanda Screens specifically to remove trash and sediment from stormwater runoff. The goal was to create a non-clogging, maintenance-free device that would remove trash from urban storm water. This technology has performed exactly as designed, and has been successfully implemented throughout the US and in the international marketplace.

Early testing revealed that pollutants other than trash and sediment were being removed. Urban stormwater runoff is known to contain solids, nutrients, heavy metals, bacteria, and varied pollutants, which negatively impact the water quality of receiving streams. Stormwater best management practices (BMP) employ both structural and non-structural controls to achieve predetermined water quality goals.

The ability of Coanda-effect Screens to remove nutrients from stormwater has been evaluated in different settings and at various locations. The purpose of this paper is to synthesize summaries the results, so that engineers and planners may have tools to evaluate water quality improvement when employing Coanda Screens.

The nutrients of primary interest in this study are nitrogen and phosphorus. The affinity of both nutrients and heavy metals to associate with particulate matter has been well documented through both research and field experience. Current approaches to gross solids removal have focused on the 5 mm mesh size, some regulatory jurisdictions such as the State of California have adopted 5 mm mesh size as the definition for full capture removal of trash from urban runoff.

The mere act of extracting such small particles from storm runoff not only removes trash, debris and suspended solids, but also a certain percentage of nitrogen and phosphorus associated with particulate matter. This study seeks to quantify the removal of both nitrogen and phosphorus in storm water runoff by Coanda Screens.

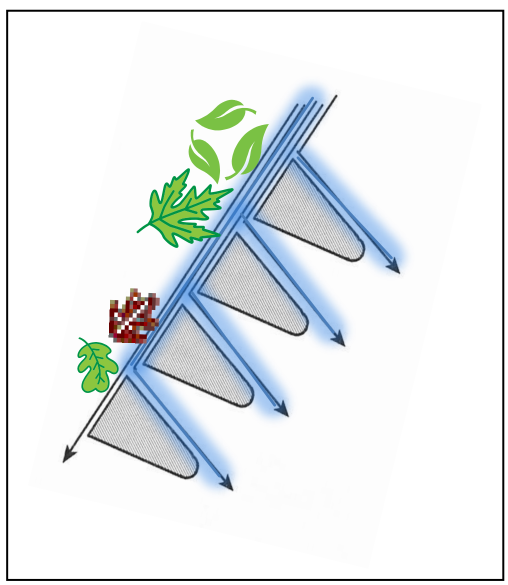

Figure 1. Cross Section of Coanda Screen

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WORKING PRINCIPLE

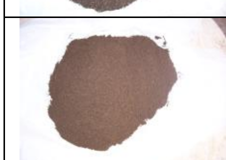
The Coanda-Effect, named after the Romanian aerodynamics pioneer Henri Coanda, describes the tendency of a fluid stream to adhere to the surface of a solid object that is placed in its path of flow.[2] As practiced in the storm water industry, shearing action also plays a part in diverting water through the screen while pushing debris past the openings of the Coanda Screen. The Coanda Effect is key to what differentiates Coanda Screens from conventional screening devices. They are very unlike other screens, in that they do not separate solids from water, but separate water from solids. Thus, water and solids are not forced to compete for the same screen openings. The Coanda-Effect also dramatically increases water velocity through the opening, helping to clean the screen, hence its self-cleaning property.[3] Refer to the graphic in Figure 1.

LITERATURE REVIEW

In a study conducted in Melbourne, Australia, it was found that particulate organic nitrogen constituted 16% of the total nitrogen in base flows and 23% in stormwater runoff.[4] Researchers have demonstrated a positive correlation between organic carbon and nitrate in different media.[5] Altabet found that particulate nitrogen in sea water was found to be mostly associated with particles in the size range of 150-300 μm.[6]

USC STUDY

The University of Southern California (USC) performed field testing, using influent and effluent sampling, to establish up to 80% removal of nitrogen by Coanda Screens.[7] Other pollutants were

Table 1. USC Study of Coanda Screens Debris Analysis			
	Description	Sieve Size, mm	% by Wt.
	Woody material (limbs, branches, twigs)		7
	Debris and leafy material (leaves, mulch, grass, fine bark)		44
	Rocks and pebbles	> 5 mm	11
	Coarse sand	>1 to <5 mm	32
	Medium sand	< 1 mm	6
	TOTAL		100

removed as well. The watershed in the USC study was an urban environment consisting of hardscapes, office buildings, sidewalks, streets, small lawns and planters. Approximately 32% of the total weight removed was less than 5.0 mm, and only 6% was less than 1.0 mm.

ROWLETT, TEXAS STUDY

Researchers in North Texas collected samples from a full-scale operating Coanda Curb Inlet BMP over the period of two years.[8] The setting is a primarily residential neighborhood consisting of manicured lawns and gardens, trees, single family residential buildings, sidewalks, and streets. During the two-year period, the BMP captured urban debris consisting mostly of leaves, grass, sand and rocks mixed with anthropogenic trash (discarded packages, cigarette butts, food scraps, etc). The observed capture rate was 22 cu.ft. per acre per year, consisting of mostly leafy material with some tree bark, sand, and urban debris having an average gross bulk density of 15 pcf. The unit removed significant amounts of nutrients, arsenic, and other water quality pollutants, including COD, As, Cd, Cu, Pb, Ni, and Zn. The average removal efficiency over the two-year period was 30% for nitrogen and 10% for phosphorus. Throughout the two-year study, the Coanda screens captured all debris, bypassed no flow or debris, and continuously cleaned the water. But most importantly, the Coanda Screens never plugged or overflowed, nor did they require any maintenance except for semi-annual trash pickup by Vactor truck.

TEXAS A&M UNIVERSITY STUDY

A pilot-scale study was performed by Texas A&M University. Coanda Screens were tested for nutrient reduction capability at flowrates representative of small to medium sized storm runoff events in McAllen, Texas.

Figure 2. McAuliffe RDF Coanda Screen

The City of McAllen, Texas installed a Coanda Channel Screen during the summer of 2012. This regional storm water treatment facility is located on a major tributary of the Arroyo Colorado River, which is a 53 mile watershed draining from west to east in South Texas, emptying in the Gulf of Mexico north of the Rio Grande River. The facility was designed to treat storm water runoff in the McAuliffe Watershed in McAllen. Known as the McAuliffe Stormwater Regional Detention Facility, this treatment facility was equipped with Coanda Screens designed to remove solids at flow rates up to 50 cfs. The Coanda screens at this facility have openings of 0.5 mm, which enables removal of all trash and gross solids greater than 500µ at all low to moderate stream flows. The facility was constructed in an existing 12 foot wide earthen channel, which flows at water depths of one foot during most of the year. Refer to Figure 2 and Figure 3.

Similar channel screen installations have been built across the US in both earthen and lined channels, with varying hydraulic capacities exceeding 1,000 cfs. The largest Coanda Channel

Screen facility in the US is in Albuquerque, NM, designed to remove solids at flows as high as 1,200 cfs.[9]

These screens were also tested in a pilot-scale setup at Texas A&M University-Kingsville for both solids reduction and nutrient reduction at flow rates representative of small to medium sized storm runoff events in McAllen, Texas. The removals of TSS and nutrients were measured at five different hydraulic loading rates, across seven ranges of particle sizes:

- <0.45μ,
- 0.45-1.2μ,
- 1.2-11μ,
- 11-53μ,
- 53-150μ,
- 150-300μ, and
- >300μ.

Removals and removal efficiencies were observed within each range. One of the key questions addressed in this study was to what extent particles less than 500 microns are removed by Coanda Screens.[10] And the main issue in this paper is to what extent are nutrients removed. Another focus area for the paper was to evaluate the removal of nutrients associated with the particles.[11]

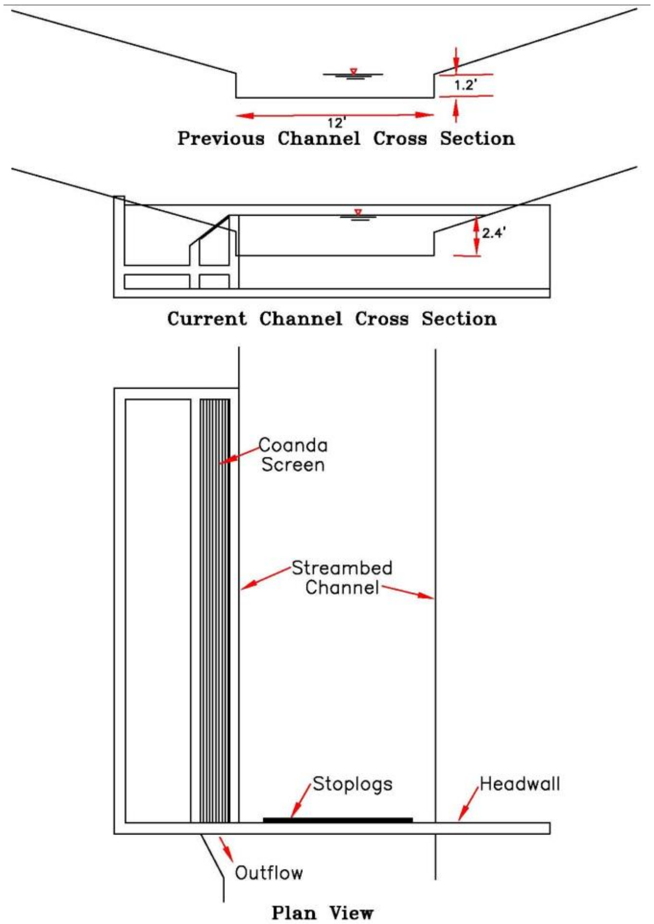


Figure 3. McAuliffe RDF Coanda Screen

DISCUSSION

Storm water was collected from a pond fed by flows from nearby Tranquitas Creek for pilot-scale testing. Water collected from the pond was a mixture of urban storm water and agricultural runoff. This source water has similar water quality with the McAuliffe Channel. Storm water from this pond was transferred by pump to a 500 gallon storage tank. This served as the source for testing the pilot-scale Coanda Screen. This provided a controlled environment and uniform feed concentrations for testing the pilot-scale Coanda Screen at varying flow rates. Both influent and effluent samples were collected, and tested for total nitrogen and total phosphorus among other parameters. Flow rates were adjusted to establish a flux rate across the Coanda Screen of 0.02 cfs/sq.ft. After samples were collected, the flow was increased to 0.04 cfs/sq.ft. so that another representative set of samples could be collected. In the same way, the screen was tested at 0.06, 0.08, and 0.10 cfs/sq.ft.

The results for total nitrogen are shown on Figure 3. It was not anticipated prior to this research that the Coanda Screen would remove significant amounts of nitrogen or phosphorus associated with particles less than 500 microns, which is the size of the openings of this Coanda Screen.

Particles smaller than the screen opening are clearly being removed, attributed to the trajectory of the flow path through the screen. In this case, a measureable amount of particulates as small as 100 microns were removed by the Coanda Screen. There is also some linearity in removal efficiency over the range of particle sizes from 100 to 500 microns.

Results for total phosphorus were similar, as seen in Figure 4. Unlike the removal efficiencies for nitrogen, there was significant removal of phosphorus associated with particles less than 100 microns. Note also the nonlinearity over the range from 0 to 500 microns, similar to what was observed with nitrogen.

This research project also attempted to address the question as to whether removal of nutrients would be a function of flow rate through the Coanda screen. Note the curves in Figure 5, showing average removal efficiencies of both nitrogen and phosphorus were about the same over the full range of flows at which experiments were conducted. The curves indicate the nutrient removal performance of the Coanda Screen is not a function of flow rate. Under normal operation, the Coanda Screen creates both the Coanda Effect, coupled with shearing action at velocities sufficiently high to prevent blockage of the screen openings.[1]

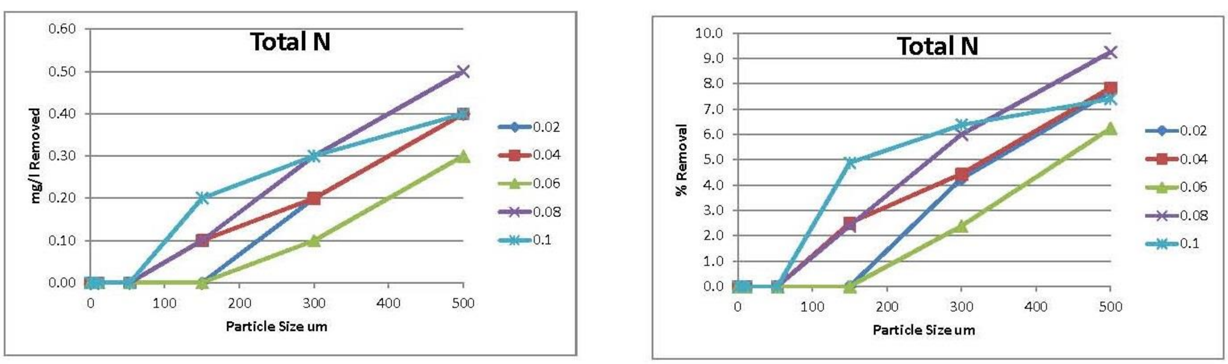


Figure 3. Nitrogen Removal

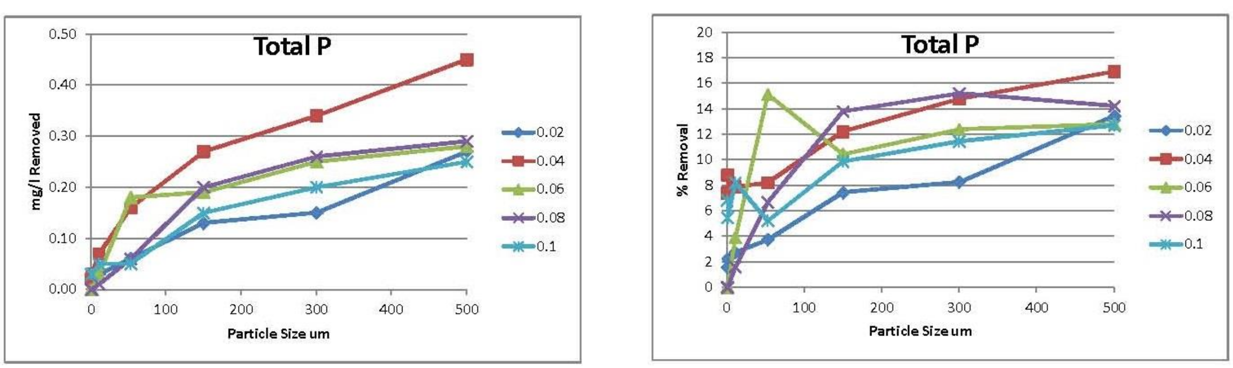


Figure 4. Phosphorus Removal

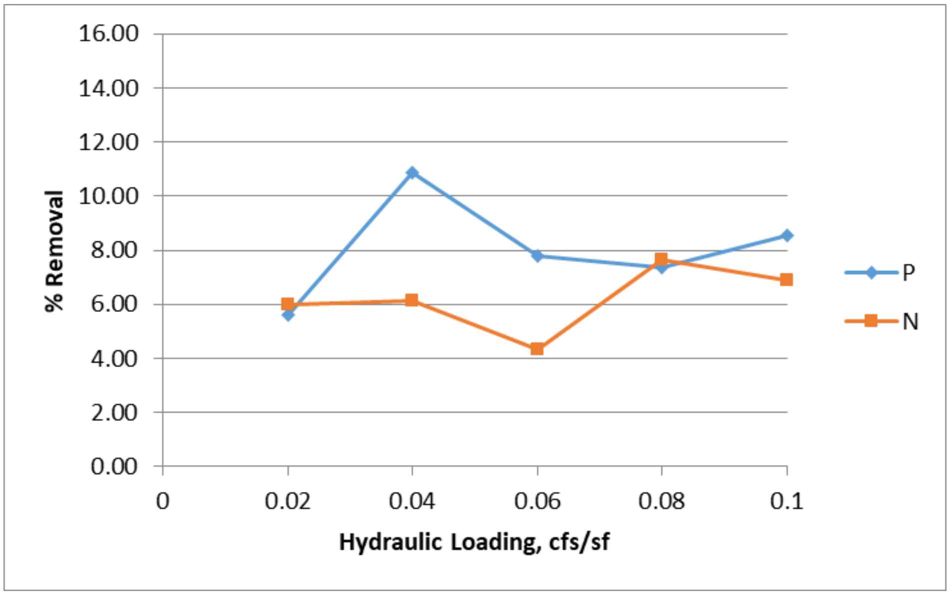


Figure 5. Removal Efficiency vs. Hydraulic Loading

Since hydraulic loading played such a minor part in the removal of nutrients, all of the influent and effluent data for all of the individual tests were combined in the presentation on Figure 6. Here we see influent and effluent concentrations for all hydraulic loadings combined.

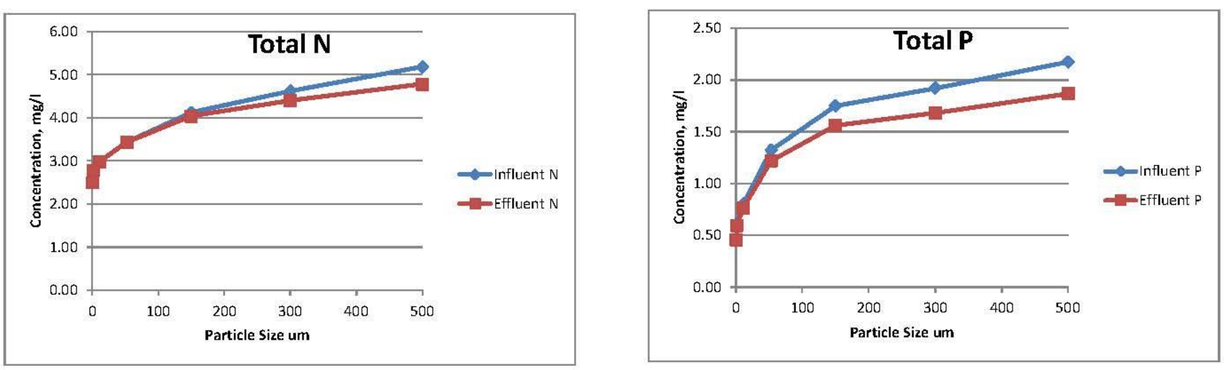


Figure 6. Influent and Effluent N and P

Reduction in nutrient and TSS concentrations at the outlet of the screen showed that it efficiently removed an average of 7.7% of TN, 14% of TP and 18% of TSS. Statistical analysis performed using Wilcoxon's Signed Ranks tests showed that nutrient removal was statistically significant. The removal rates of nutrients bound with particulates <300µ in size were almost unaffected under all five hydraulic loading scenarios which were tested. This research also proved that Coanda Screens are quite capable of removing both solids and nutrients associated with particulate matter in the smaller particle size ranges, significantly smaller than the screen openings.

This study should be interpreted in the context alongside other studies of nutrient removal using Coanda Screens. The statistically significant removal rates are site specific and depend heavily upon conditions and land uses in the watershed. Refer to the comparison on Table 2.

Table 2 – Nutrient Removal Comparison with Other Studies			
	% Removal		Comments
	TN	TP	
University of Southern California	80	(Not Tested)	Highly urbanized environment, mostly office buildings and streets, dominated by anthropogenic trash along with some green waste.
Rowlett, Texas	30	10	Residential land containing lots of green waste and sediment, less anthropogenic trash.
Texas A&M University	8	14	Relatively clean suburban stormwater containing agricultural runoff with algae, small amounts of anthropogenic trash and green waste.

CONCLUSIONS

This paper has provided a synthesis of three independent, peer-reviewed studies, aimed at investigating nutrient removal in stormwater using Coanda Screens. While these screens are intended primarily for separating trash and sediment from stormwater, they provide the added value of removing a certain amount of nutrients and other substances normally regarded as pollutants. Nutrients, like many other chemicals, tend to dissociate into soluble and non-soluble fractions. The non-soluble fraction is typically adsorbed on solids, which the screens remove with great effectiveness.

This paper has quantified the nutrient removal capacity of Coanda Screens in urban stormwater. This collective body of research could be used for planning purposes as well as qualifying the Coanda Screen technology as a nutrient removal device.

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