INTRODUCING A NEW MEDIA FOR FIXED-FILM TREATMENT IN DECENTRALIZED WASTEWATER SYSTEMS

Kevin M. Sherman

Director of Engineering, Quanics, Inc., PO Box 1520, Crestwood, KY 40014-1520

ABSTRACT

Both naturally occurring and artificial media have been used to treat wastewater in small community settings. Systems using naturally occurring media include sand filters and peat-based biofilters. Artificial media include open cell foam, textiles, and plastics. All the above operate as fixed-film systems, in that attached growth microorganisms are encouraged to colonize and reproduce in the media. Fixed film systems appear to produce a more consistent effluent under peaked sewage inputs and periods of no use (vacation homes, weekend retreats) compared to suspended growth systems in this flow range. Naturally occurring media have advantages in that naturally occurring fauna and flora may already be present in the media. Start up is therefore shortened because colonists are already present in the media and just need to multiply to handle the waste renovation process. A disadvantage of naturally occurring media is that they must be mined. Extraction of these natural resources is sometimes criticized because they formed over thousands of years. They will eventually be exhausted and will not be replaced. Quanics. Inc. has patented a product that combines advantages of both artificial and naturally occurring media. The Bio-COIR™ filter uses coir, the recycled husks of coconut in a biological fixed film filter. The material is a waste product of agricultural operations in developing countries. The product has successfully passed NSF Standard 40 certification. Systems in the ground for two years show virtually no change in media properties except a slightly darker color, giving the expectation that the media will continue to function for a comparable period to peat (8 to 16 years between media replacement).

KEYWORDS.

Attached growth, Coir, Fixed Film Wastewater Treatment, Onsite wastewater

INTRODUCTION

A variety of media have been used to treat wastewater. In the small community sector, both naturally occurring and artificial media have been employed. Systems based on naturally occurring media include sand filters and peat-based biofilters. Artificial media include open cell foam, textiles, plastics, and recycled, ground glass (Stuth and Garrison, 1995).

All such filters operate as fixed-film systems, in that attached growth microorganisms are encouraged to colonize and reproduce in media. Under these circumstances, wastewater must be brought to the microorganisms living in the media under aerated conditions and applied at light enough dosages to encourage effluent flow via thin films throughout the media surfaces. Because attached microorganisms cannot move to areas with sufficient food or free oxygen, these necessities of life must be brought to them. Because water is denser than air, the energy requirements for attached growth systems are therefore higher than for suspended growth systems.

There are other differences between suspended growth and attached growth systems. The reader is directed to Sherman, 2006 for details on some of these. In this paper, the major distinction to be highlighted is system performance under peaked loading conditions. In suspended growth systems, the microorganisms responsible for treatment float freely in the aeration chamber. Under a regimen of consistent sewage inputs, stable populations develop that can rapidly aerobically stabilize wastewater (Tchobanoglous, 1991). However, in gravity-fed systems, if sewage loads temporarily exceed anticipated values, the unit may 'burp' activated sludge out of its clarifier. This situation is not cause for alarm if the unit is connected to a standard drainfield. The high dissolved oxygen in the effluent will soon reach the escaped microbial cells and allow their complete aerobic digestion. The author has dug into over a dozen drainfields associated with functioning suspended growth Aerobic Treatment Units of various manufacturers and has yet to encounter a restricting layer or biomat. However, the number of microbial cells, or activated sludge, left in the aerator has been diminished (Hutzler, Waldrop and Fancy, 1978).

Gravity-fed Suspended Growth ATUs are most common in single-family home settings. They operate under the hydraulic displacement principle. In simple terms, when one gallon flows into the unit, the effluent level inside the unit rises until one gallon exits. Consequently, hydraulic detention time in the aeration and clarifier chambers is variable. Under unanticipated high loading (e.g., fifty gallons in), not only have some microbial cells left the clarifier because their settling velocity was less than the exit velocity up and out of the clarifier, the time that a parcel of water has spent in the aeration chamber is shorter than usual. $CBOD_5$ and TSS in the effluent will therefore temporarily be outside of accepted values (Bennett, Linstedt and Felton, 1975).

The very efficiency of aerobic microorganisms works against them under periods of low or no sewage inputs. Now the activated sludge microorganisms are not being fed enough. Because these microorganisms are free-floating they are able to encounter each other and are able to eat each other. The microbial populations under extended periods of under feeding changes to a 'pin floc' condition. In this state the few remaining microorganisms are in torpor. When fresh sewage is again added to the unit, there will be a lag time until the microorganism population size and vitality are restored.

Because of the above, when aerobic treatment is desired the attached growth process is indicated for intermittent and extended high or no flow situations. Examples of establishments where these flow patterns occur are vacation homes, weekend retreats, churches, flea markets and rental properties.

The start up period for natural media filters is shorter than for artificial media filters. This is because natural media already contain low numbers of microorganisms, flora and fauna. Their reproduction provides the biomass needed for sewage treatment (Brooks, Rock and

Strochtemeyer, 1984). In artificial media the assumption is that the organisms responsible for renovating wastewater must first colonize, then reproduce in the media for effective treatment.

Coir fiber

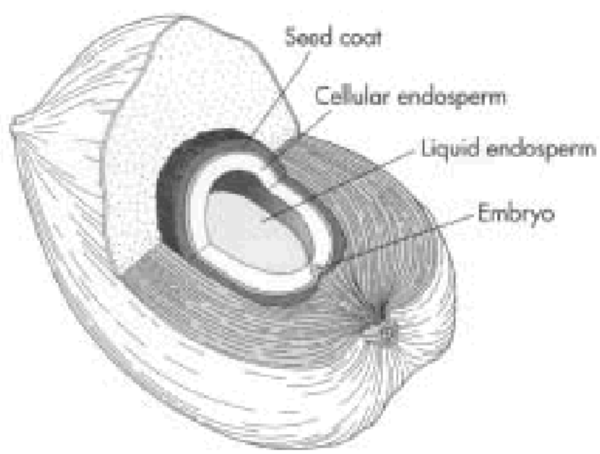
Coir (rhymes with 'lawyer') is the natural fiber found within the shell of the coconut. Coir fiber and the associated pith or coir peat work to cushion the inner nut and prevent it from breaking when the mature coconut falls from a tree. Coir fiber is strong, flexible, and durable. Coir has become a popular material in many products. Because of its tough and scrubby nature it is an ideal fiber for outside door entry mats. Coir fiber is also used in other types of mats, baskets, erosion-control blankets, as soundproofing material and in car seat cushions.

NATURAL HISTORY OF THE COCONUT

Coconuts are fruit of the tree *Cocos nucifera* L. Varieties of the species are found in wet tropical areas throughout the world. Coconuts grow beside virtually every major tropical ocean. They are found on islands in the Caribbean Sea, in Latin America, East Africa, India and Southeast Asia, and on islands in the Pacific Ocean.

The anatomy of the coconut features three distinct layers (Figure 1). The glossy outer shell surrounds the husk that in turn surrounds and protects the inner shell. The husk layer is composed of coir fiber and a spongy material called pith or coir peat. The inner seed, kernel or endosperm contains the most economically valuable coconut products. Flake coconut, or copra is the most recognizable product from the kernel. The inner seed also contains coconut milk and coconut oil. The oil is used to light lamps in religious ceremonies in India. There the coconut tree is called 'Kalpavriksha', the all-giving tree. The use of coconut throughout India makes it a symbol of national unity.

Figure 1: Anatomy (cross section) of the coconut



The coconut tree grows 60 feet tall, on average. Mature coconuts weigh almost two pounds. They fall from the tree top to the ground below with great force. The husk's first role then is to cushion the endosperm through this traumatic period. The tough impenetrable skin (glossy outer shell) protects the endosperm from predators in the area where the coconut fell. The coconut will sit in place until a monthly high tide washes the coconut out to sea. In addition to its strength and durability, coir is the only natural fiber able to withstand prolong submergence in sea water. After a long period (nine months to a year or more) at sea, the coconut washes up on a distant shore. The husk opens and the coir peat provides a hospitable environment for the endosperm to germinate in place.

Coconuts are naturally a coastal species. A mature tree can produce 70-100 coconuts a year. A tree will begin producing coconuts within 6 years of planting. Over centuries vast coconut plantations have been created simply by transplanting the seeds. Not all areas are suitable for coconut trees. A tree cannot withstand temperatures below 32^{o}F (0^{o}C), and will not thrive unless the annual average temperature is at least 72^{o}F (22^{o}C).

Table 1 details the annual production of coconut meat (copra) worldwide from 1979 to 1998. Note the dominance of production in Asia, with nearly 90% of the worldwide production. Also note the tons produced are steadily increasing. In 1979-81, 35 billion tons of copra were produced. By 1997-98 production had grown by nearly 40 percent to 48 billion tons.

The countries on table 1 produce goods from the kernel of the coconut. In the majority of coconut producing countries, husks are burned as fuel, used as an amendment to manure or simply discarded. In Thailand, India, Sri Lanka and east Africa, additional products are made from the coconut's husk. India and Sri Lanka lead the world in production of coir fiber. Current production is estimated at 350,000 Metric tons. This production occurs despite only 10% of the available husks in these countries entering commercial trade.

A coconut husk weighs approximately 300 grams. Of this 200 grams is the soft mossy coir pith. About 100 grams is coir fiber. Most of the fibers (60%) in a coconut husk are longer than 4 inches. About 20% of the fibers are between 4 and 2 inches. The remaining 10% of the fibers are shorter than 2 inches.

Coir fibers are classified as "Brown" or "White" coir. The darker brown coir fibers are long and stiff. Perfectly straight fibers are used primarily in brooms and brushes. The rest is used as mattress filler. White coir fiber is really a golden brown color. These fibers are woven into rope, door mats, baskets, air conditioning filters, sound proofing material, insulation and soil erosion control products. Coir contains the highest lignin content of any natural fiber at about 45%. Lignin is a natural polymer and gives coir it elasticity and strength. In addition, coir is the only natural fiber adapted to prolonged exposure to sea water. Coir fiber is more resilient and longer lasting than either sisal or abaca, two competing natural fibers. The high lignin content also makes the fiber resistant to biodegradation.

The spongy pith material is being touted as an environmentally friendly alternative to sphagnum peat moss in horticultural applications. The size of the horticultural market far exceeds that of peat materials used in wastewater treatment. Peat resources cover approximately 40 million square kilometers of the earth. Major deposits are currently being harvested in Ireland, Canada

Table 1. Coconut production in major producing countries 1979-1998, in Millions of Tons

COUNTRY	1979-81	1988-90	1991-93	1994-96	1997-98	%
Indonesia	11 200	12 317	14 380	13 990	14 710	30.3
Philippines	9 142	8 910	9 079	11 586	11 273	23.2
India	4 192	6 188	7 590	9 718	9 900	20.4
Sri Lanka	1 692	1 828	1 689	2 009	1 999	4.1
Malaysia	1 211	1 061	1 033	1 003	967	2.0
Thailand	781	1 433	1 379	1 433	1 430	2.9
Other Asia	564	1 312	1 553	1 666	1 825	3.7
Total Asia	28 782	33 048	36 703	41 405	42 104	86.7
Mozambique	453	420	425	439	445	0.9
Tanzania	310	358	357	370	355	0.7
Other Africa	890	1 158	952	975	1 011	2.1
Total Africa	1 653	1 936	1 734	1 784	1 811	3.7
Oceania	2 317	2 213	1 891	1 866	1 878	3.8
Latin America	2 266	2 807	2 945	2 359	2 311	4.7
TOTAL WORLD	35 018	40 005	43 274	47 854	48 525	100

and the northern United States, with an annual extraction estimated at 800 cubic kilometers (Joosten and Clarke, 2002). Proponents of coir based peat like products (trade names coco peat coir peat) point out that peat bogs contain rare plant and animal species and priceless historical artifacts (Klesius, 2000). These resources are threatened because mechanized methods are used to harvest and process peat. Of greater significance, peat bogs form very slowly over time, at an average rate of 1 mm/year. As the rate of peat extraction exceeds the rate of accretion by two-hundred fold, the resource will not be sustainable long-term. In comparison, coir peat uses a waste product of agriculture operations in developing countries. Use of the material in horticulture reduces stockpiles of a difficult to store and dispose commodity. It is an example of a renewable resource being beneficially used.

COIR PRODUCTION

The coir production process is lengthy and labor intensive. First, the coconut is cored to remove the kernel. Husks are then soaked in salt water lagoons for up to ten months. The process is called 'retting'. To keep the coconut husks from floating away, they are covered with a layer of mud. The creation of retting mounds is extremely labor intensive. Husks are stockpiled and retting is begun during the agricultural 'off-season'. At the end of this process the coconut fibers are softer and more elastic.

The retted husks are then removed from the lagoons using canoes and defibered in threshing compounds. This is accomplished by primarily young women using a mallet or machete Fibers are then pulled off and collected. The work is difficult. Baskets of fibers are next shipped to coir 'factories'. The term is not accurate as these building are little more than sheds or pole barns and lack electricity.

At the spinning sheds, an all female workforce hand spins the two inch long pieces of coir into strings of yarn up to 60 feet long. This is accomplished by having a spinner at a wheel to which is attached a gear with a small spinning axel. The women spinners stand two at each wheel and each wheel has two gears. Each woman attaches a handful of fibers from her basket to each of the two gear ends; the spinner starts to spin; and the women walk backwards swiftly, pulling fibers from their baskets to attach deftly to the spinning and lengthening yarn. After walking backwards for about 30 feet, each woman begins to lace together the two strands as she walks forward towards the spinner, creating a stronger yarn strand. After approaching the wheel, she pulls off her newly created thread and hangs it on a nearby wall, then runs a few fibers around the axel to start over.

Coir yarn can be woven into high quality and attractive mats. Weaving is the most skilled part of the production process. It is done mostly by men and the pay is somewhat higher than for other parts of the production process.

WASTEWATER TREATMENT USING BIOCOIR™

The waste products from the weaving process are short and medium coir fibers. These are washed to remove salts, dried and compressed from 4:1 to 8:1 into bales for shipment. Upon arrival in the United States, the fibers are allowed to decompress and then loaded into watertight fiberglass modules. Use of the media is patented and a patent pending process is used to ensure a uniform distribution of media with a consistent ratio of void space to media of approximately 3:1.

Effluent is delivered across the entire media surface through the use of helical spray nozzles pointed down. The pressure is adjusted to ~5 psi. This setting provides even distribution of effluent without short circuiting or channeling of effluent. Helical spray nozzles snap on and off over a pre-drilled 13/16" hole. This allows quick and easy cleaning debris out of nozzles on a 6-month basis.

Research and development of coir began in 2003. All testing results, marketing and patents were transferred to Quanics, Inc. in February of 2006. Initial testing was conducted at the Massachusetts Alternative Septic System Test Center in Buzzards Bay, Massachusetts. Testing was conducted to determine the optimum mixture of coir fiber and coir pith (pith was excluded from the media), and dosing rate (optimum of approximately 5-10 gallons per cubic foot of coir per day). Open cell foam was used as a control in side-by-side testing. Both composite and grab samples were used in this phase as appropriate. Other variables that were researched included depth of media (30 inches found to be optimal), and recirculation ratio for nitrogen removal. 80% recirculation with provision of adjustment for low flow periods was found to be optimum.

The BioCoir™ system has been performance tested under ANSI-NSF standard 40 at the Massachusetts Alternative Septic System Test Center and at the NSF facility in Waco, Texas. The unit was certified under ANSI NSF standard 40 testing in November of 2005. The average $CBOD_5$ of effluent from the system was 9 mg/L. The standard requires a 30-day average of 25 mg/L for $CBOD_5$. The average TSS of effluent from the system was 12 mg/L. The standard requires a 30-day average of 30 mg/L. Total nitrogen, although not required under standard 40, was also sampled during performance testing. The average total nitrogen in effluent was 17 mg/L.

Following successful completion of standard 40 testing, additional stress testing of the unit began under direction of the company. Loading rate of the already in use module increased in several steps to 2.5 times the original loading. After 6 weeks of this loading, hydraulic failure of the unit occurred. Just prior to failure, effluent quality began to decline.

Figure 2 – Oxygen demand over performance testing period 5/2/2004 to 10/28/2004

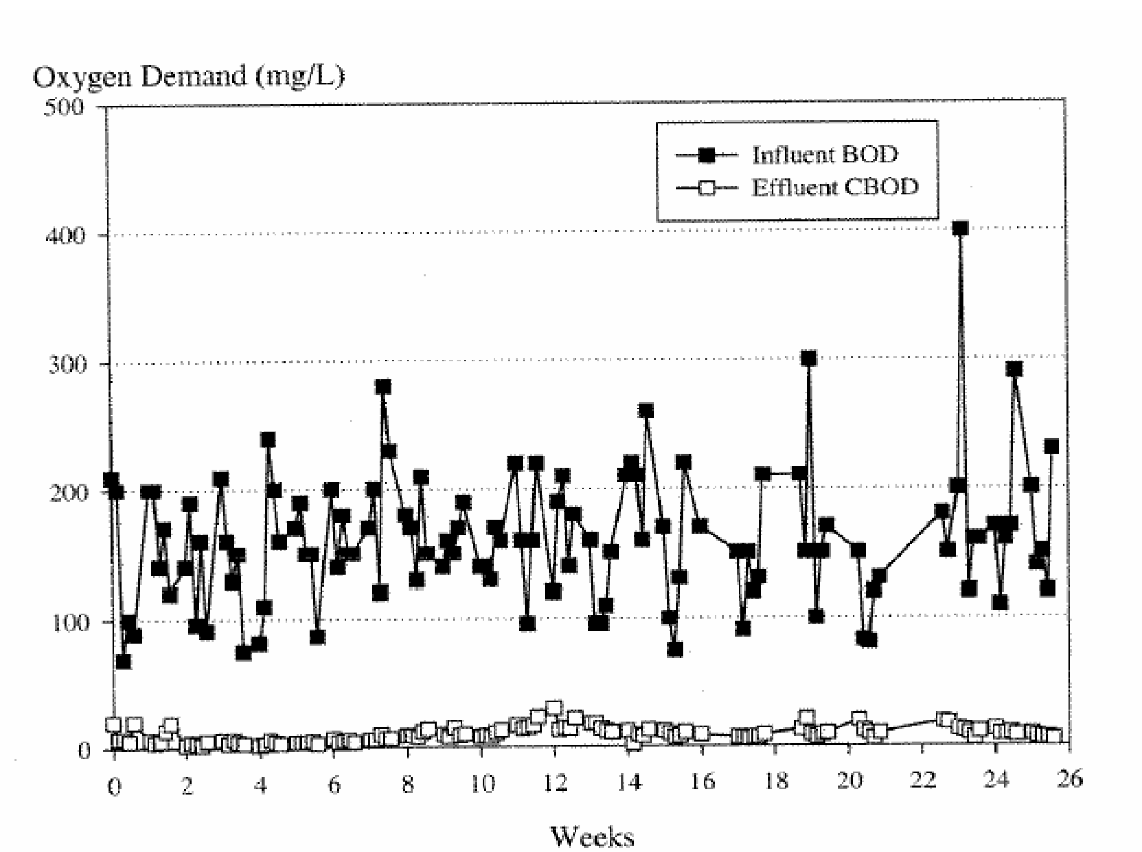
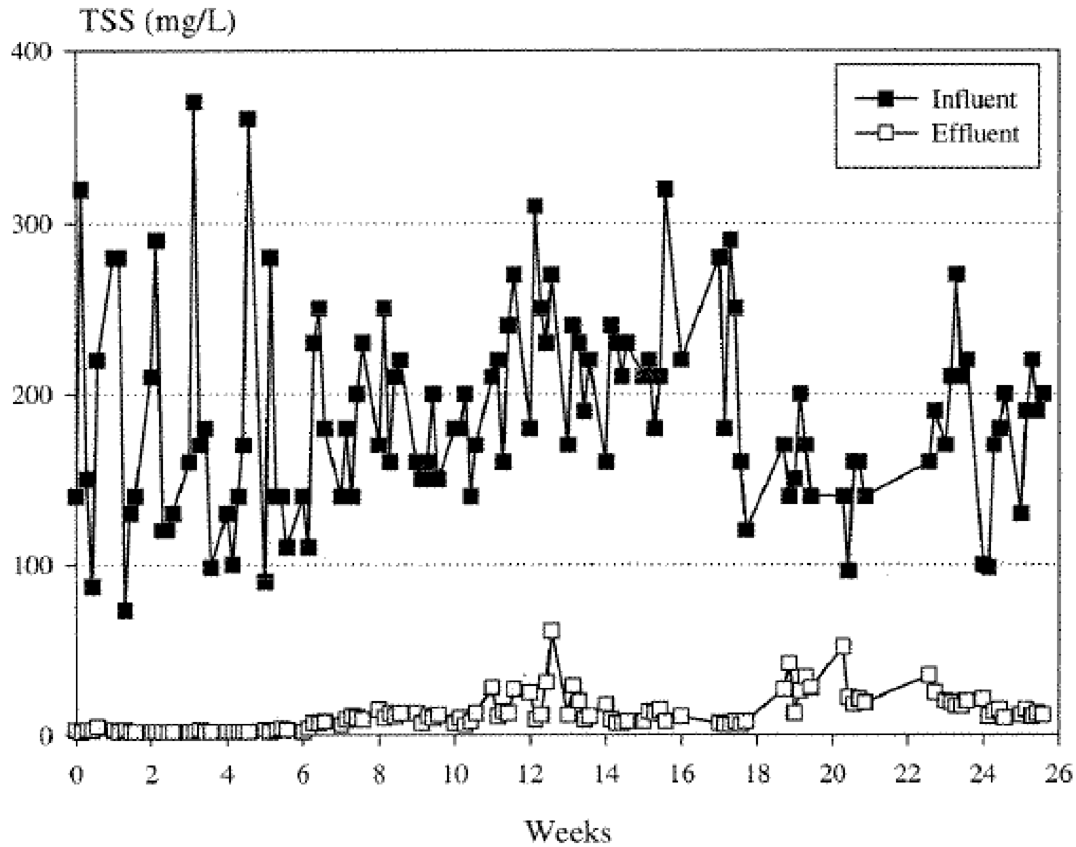


Figure 3 – Total suspended solids over performance testing period 5/2/2004 to 10/28/2004



This unit was tested under controlled conditions and was fed the same volume of wastewater each day, in three distinct daily doses. These are much more controlled conditions than would occur in the real world.

As is typical of attached growth systems, both figures show an effluent (open squares) that does not vary excessively despite large deviations in the concentration of the influent wastewater. Note that beginning in week 17 a series of stress tests were performed on the unit. Wash day stress was followed by working parent stress in weeks 18-19, followed by power equipment failure stress in weeks 21 and vacation stress over weeks 22-23.

An important consideration in natural media is longevity. In other words, how long will it take before the media will need to be replaced? Over time peat materials degrade to a muck material. The time required to degrade varies from peat source to peat source, but ranges from 8-16 years. Coir material will also degrade to a muck-like material over time. When its treatment ability is exhausted, it can then be pumped out of its container with a liquid vacuum pump truck. The spoil material will be taken to a septage processing plants and can be land applied.

The coir system with the longest continuous use in the country is on the Quanics Chairman of the Board's residence in Northern Kentucky. It was installed on July 1, 2005 as a single pass addition to an existing permitted system in Oldham, County. Media sampled from the surface of the unit on May 31, 2006 showed no deterioration, just a slight darkening of the coir color. Based on these promising early results, an anticipated longevity between 8-16 years appears reasonable.

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