VETIVERIM

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Editorial

Vetiver Fights Back

Communities at Nong Nae Sub-district, Phanom Sarakham District, Chachoengsao Province, Thailand has suffered from illegal dumping of industrial wastewater containing high phenol for more than two years. Phenol migrates from the dumping sites causing contamination of shallow-well groundwater as well as Tat Noi Creek, the main creek of the villagers. All of the villagers there utilize shallow-well groundwater as their sole drinking water source. It is therefore obligatory to reduce the phenol content in the creek and underground water in order to protect community's health.

A group of researchers from the Faculty of Engineering, Naresuan University in Phitsanulok Province, under the leadership of Dr. Tanapon Phenrat, has conducted an experiment by growing vetiver on a floating platform. They found that phenol concentration during the period of 15 days remained unchanged. However, it was rapidly decreased soon after that initial period, down to the level that meets the effluent standard (1 mg/L) within only six weeks. After the experiments, phenol was extracted from leaf, trunk and root of the vetiver grass and found very small amount of phenol remaining in the vetiver parts. This suggests that vetiver degraded phenol by enzyme-assisted degradation and not just removal by absorption. This successful laboratory evaluation gives confidence and insight necessary for conducting a pilot-scaled treatment of illegal-dumped wastewater contaminated with phenol at Nong Nae Sub-district in the near future.

In other system of phytoremediation, vetiver roots grown hydroponically could absorb organic and inorganic contaminants in the water. This is not what happens to phenol. Vetiver roots, although not being suffered by the presence of high concentration of phenol, did not absorb it into its structure during the first 15 days. Soon after that, it *fights back* by producing the enzyme (peroxidase) to degrade phenol to the extent that it was down to 1 mg/L, the safe effluent standard.

It can be concluded that vetiver is a marvelous plant that it is able to *fight back* its aggressor by degrading them with the enzyme induced by the presence of the aggressor, i.e. phenol. It remains to be seen that vetiver can do the same job when planted along the rim of the waterway loaded with phenol compound from the site of its dumping.

Vetiver Grass Degrades Phenol in Illegally Dumped Wastewater*

Communities at Nong Nae Subdistrict, Phanom Sarakham District, Chachoengsao Province, Thailand has been suffered from illegal dumping of industrial wastewater containing high concentration of phenol (C_6H_6O) (as high as 500 mg/L) as well as other hazardous organic substances such as petroleum hydrocarbons (TPHs) and formaldehyde and metals such as arsenic, chromium, iron, copper, lead, nickel for more than two years. The most widely spreading contaminant is phenol according to its hydrophilic nature. Phenol is a toxic substance causing irritation and kidney inflammation. If phenol-contaminated water is disinfected by chlorination to produce drinking water, chlorophenols (carcinogenic substances) will be formed and pose even more serious threat to villagers' health. Phenol migrates from the dumping points causing contamination of shallow-well groundwater and Tat Noi Creek, the main creek of the villagers. All of the villagers there utilize shallow-well groundwater as their sole drinking water source. Various government agencies monitored the contamination and reported that phenol concentration in shallow-well groundwater exceeds the maximum contamination level (1 μg/L) for more than 250 times in households downstream the direction of shallow groundwater and Tat Noi Creek. In order to protect community's health at Nong Nae, decreasing phenol exposure to the villagers is mandatory.

We are conducting an on-going research aiming at using vetiver systems to protect the Nong Nae community by degrading phenol and other contaminants both in the accessible, remaining illegal dumping source zone and those migrating through surface water (Tat Noi Creek) and shallow groundwater. As a result, the first step is to understand dominant phenol degradation mechanisms by the vetiver systems. Vetiver can produce hydrogen peroxide (H_2O_2) and peroxidase in response to the irritation caused by phenol in wastewater. The release H_2O_2 and peroxidase to wastewater can eliminate phenol. Two possible phenol removal mechanisms are phenol transformation to: (i) polyphenol by H_2O_2 and peroxidase, and (ii) CO_2 by H_2O_2 and Fe^{2+}. We name the latter reaction, phyto-fenton. Here, we conducted laboratory experiments using floating vetiver platforms with five different amounts of vetivers (from P1 (20 vetivers) to P5 (100 vetivers) (see Figure 1). Phenol at the concentration of 500 mg/L was used in the experiments. In each experimental condition, we monitored phenol concentration as a function of treatment time (t) (reported as phenol concentration at time t divided by phenol concentration at time zero (C/C0)) as well as concentration of H_2O_2, peroxidase, chemical oxygen demand (COD), oxidation reduction potential (ORP), microbial growth, and other by-products including polyphenol and volatile organic acids. The first 400 to 600 hours of phenol degradation was dominated by phyto-fenton, a newly discovered, self-sustained chemical reaction (black lines in Figure 1). We have several evidences to support this proposed mechanism. Fenton reaction is advanced oxidation reaction by Fe^{2+} and hydrogen peroxide (H_2O_2) to create short-live hydroxyl radical (•OH) which can rapidly degrade hazardous organic contaminants such as phenol and TPHs. In the case of phyto-fenton reaction discovered in this study, iron (Fe) is available in the illegally dumped wastewater. Due to high organic contaminant loading, Fe is in the reduced form as Fe^{2+}. Then, vetiver releases hydrogen peroxide (H_2O_2) from the root to interact with Fe^{2+} yielding •OH and Fe^{3+} to degrade phenol to CO_2. Fe^{3+} is reduced by TPHs and other contaminants in the contaminated water to yield Fe^{2+} which can undergo a new round of powerful phyto-fenton reaction to degrade phenol until the contaminated water is completely detoxified. This mechanism is supported by the fact that as shown in Figure 1 phenol was degraded at the maximum rate constant of 3.2×10^{-3} per hr, and P2 and P5 were fastest in degrading phenol. Interestingly, the rate

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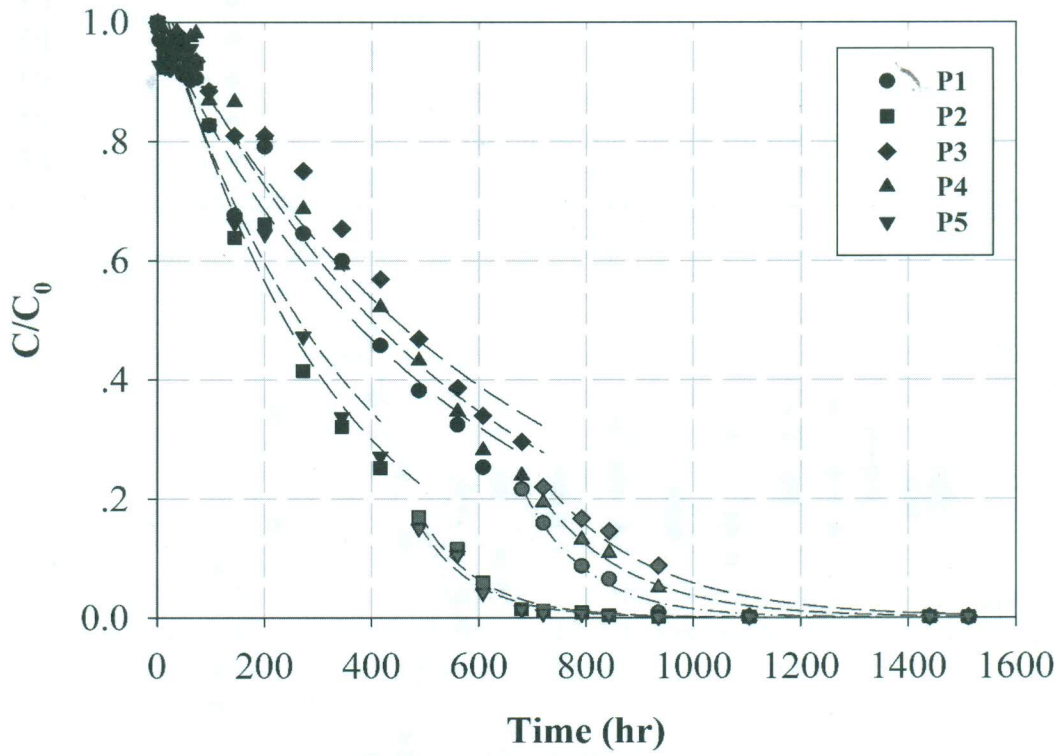

Figure 1. Phenol degradation kinetics by phyto-fenton (black) in combination with rhizomicrobial degadation (blue)

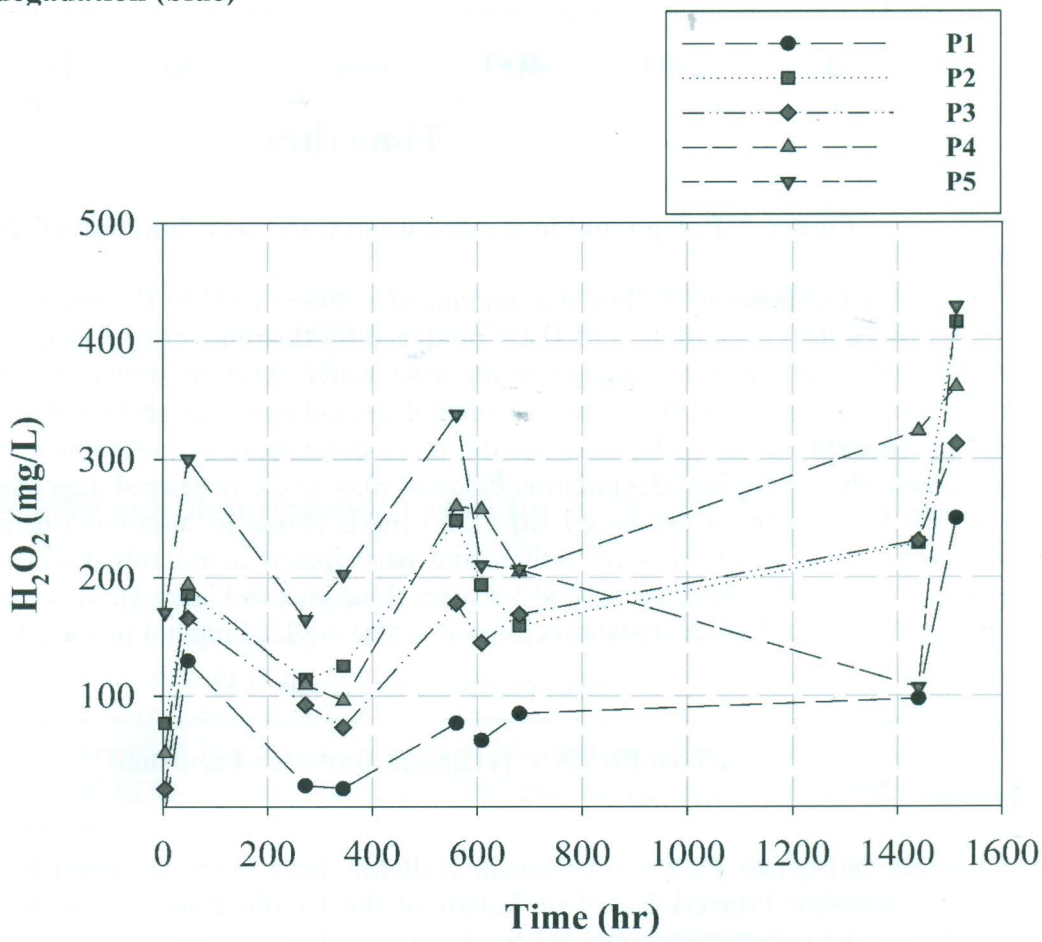

Figure 2. H_2O_2 Produced by Vetiver

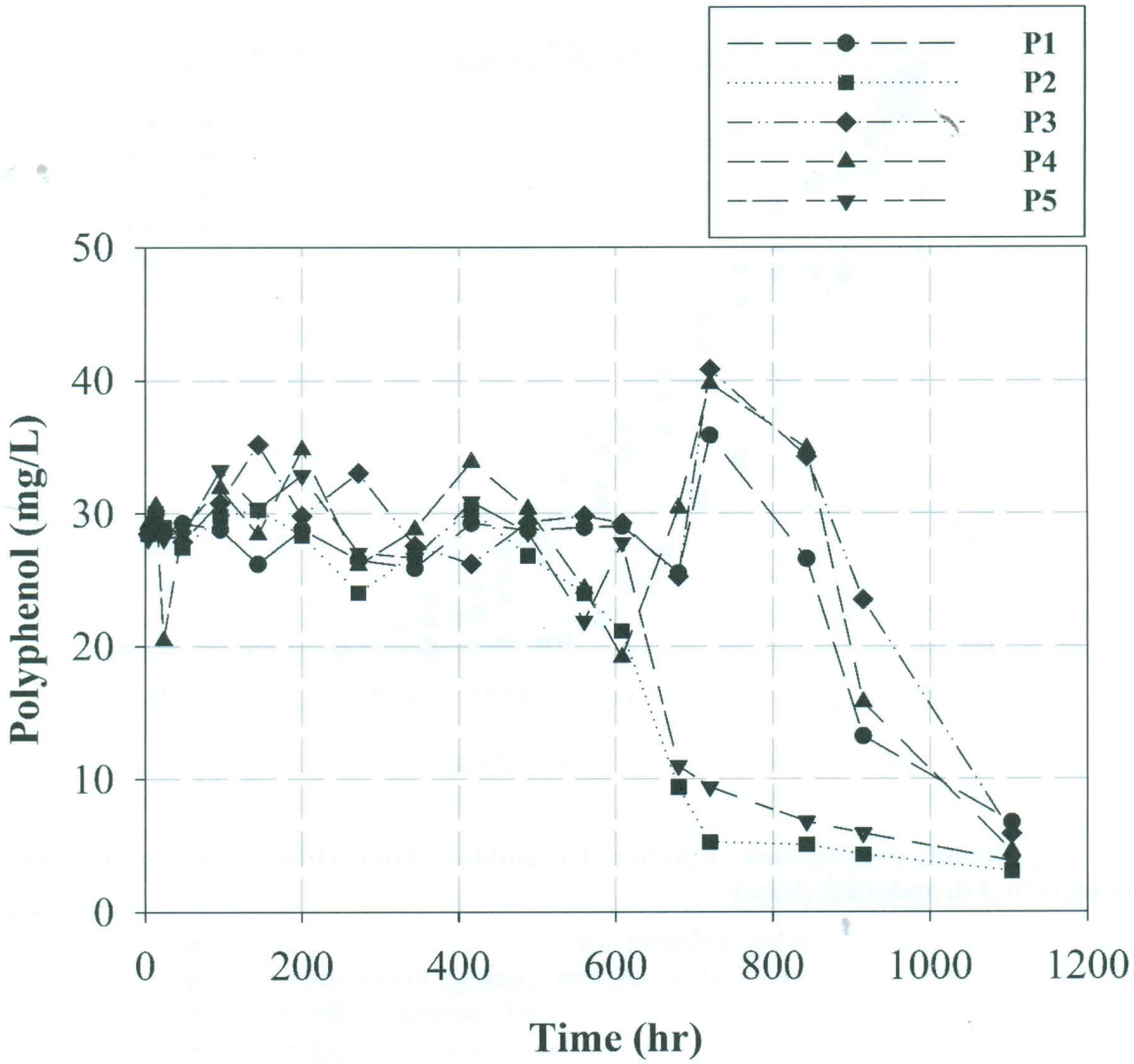

Figure 3. Polyphenol in treated wastewater as a function of time.

constant did not completely follow the amount of vetivers used in the treatment. As a matter of fact, it followed the concentration of H_2O_2 produced by floating vetivers (see Figure 2, P5 formed H_2O_2 the most) and iron concentration in the wastewater. Also, as shown in Figure 3, polyphenol was not accumulated over the course of phenol degradation, suggesting that polymerization of phenol by peroxidase and H_2O_2 was not the main detoxification mechanism. Interestingly, after phyto-fenton, rhizomicrobial degradation came to play a role in phenol degradation. After around 400 to 600 hours, phenol decreased from 500 mg/L (toxic to microbes) to around 100 mg/L; rhizomicrobe grew on the root of vetiver and participated in microbial degradation of phenol, increasing phenol degradation rate around 3.5 times (blue lines in Figure 1). This combination of phyto-fenton and rhizomicrobial degradation eliminated 500 mg/L of phenol in wastewater in 800 hours.

(See photographs on page 14)

Two PRVN's Technical Bulletins Published

During 2014, two PRVN's Technical Bulletins have been published by the Office of the Royal Development Projects Board on behalf of the Pacific Rim Vetiver Network. Due to the availability of the manuscripts prepared by the author, Dr. Paul Truong, whose format is different from that of the previous ones in that they are directly taken from his PowerPoint presentations, thus they are published as such, and in color throughout the volume. They are:

1. **"Extreme Slope Stabilization Using Vetiver System" by Paul Truong, TVNI Technical Director.**

This is the first bulletin for 2014 (TB No. 2014/1 – February 2014) with 56 pages in full color. It deals with the use of the vetiver system in stabilizing extreme and highly erodible slopes without geofabrics and no hard structure, with geofabrics, and with hard structure. The author first introduced vetiver geotropism research conducted by P.K. Yoon and P. Truong, clearly showed geotropism strongly affected vetiver growth and development, then with full illustration, showing the options for slope protection, the results of a series of experiments with slopes ranging from 30-80^{o} in Indonesia, the successful applications of VS on extreme slopes, without geofabrics (in Australia, Brazil, China, Colombia, Ecuador, Hong Kong, Indonesia, India, Madagascar, Philippines, Thailand, USA (Hawaii), Venezuela, and Vietnam) with geofabrics (in Australia, Brazil, Guatemala, Guinea and Congo), with sand bags (in Congo), with eco-mortar (in Colombia), with soil nails (in Colombia, Vietnam) and with geogrids (in Brazil). At the end, the author shows some instruments used on these extreme slopes such as hole punchers mounted on a backhoe to make holes for vetiver planting on the steep wall, ladder and portable drill.

2. **"Socio-Economic Benefits of the Vetiver System Technology on Mining Areas in Developing Countries" by Paul Truong, TVNI Technical Director, and CEO and Principal Consultant of Veticon Consulting, Brisbane, Australia.**

This is the second bulletin for 2014 (TBV No. 2014/2 – November 2014) with 20 pages in full color. It contains four chapters, viz.: 1: The vetiver grass describing morphological and physiological attributes, adaptability ranges, threshold levels of heavy metals in vetiver growth. 2: VST and Applications whose main topics include: Soil and water conservation in farmland, infrastructure protection by bioengineering, wastewater treatment, mine rehabilitation, fresh gold tailings, flexibility vetiver hedges and poverty alleviation. 3: benefits of VST in mining areas in developing countries: Rural employment – handicraft production in Venezuela. 4: Case studies of benefits of VST in Africa, Latin America and Asia with four Case Studies, viz.: (i) Madagascar (describing demographics, erosion and sediment control of highly erodible sand dunes, the Project, nursery establishment training, and employment and technical training, (ii) Venezuela, (describing poverty alleviation and rural employment, VST for erosion and sedimentation control, (iii) Vietnam (describing infrastructure protection, community nurseries along the highway, local employment during implementation phases, and (iv) Africa (describing some major mining projects in Africa, excessive erosion caused by surface water runoff, before and after VST application for slope stabilization, and installing erosion control structures, VST and hydroseeding.)

Exhibition of Vetiver Handicraft and Vetiver Textile in Thailand

The Faculty of Architecture, Phra Chom Klao Chao Khun Thahan Lat Krabang Institute of Technology, the PTT Public Copmpany, and the Chaipattana Foundation jointly organized the Exhibition of Vetiver Handicraft and Textile, held at the Paseo Shopping Center, Ram Khamhaeng, Hua Mak in Bangkok during 13-18 December 2014. Such an exhibition is a part of the project on the "Design of of Textile Products from Vetiver" for the Pat Pat Shop of the Chaipattana Foundation in order to develop the knowledge on the utilization of vetiver leaves for economic development of the community's economy.

The activities included: (1) the exhibition on the prototype of the design of the fifth-year students on textile design of the Faculty of Architecture, Phra Chom Klao Chao Khun Thahan Lat Krabang Institute of Technology, (2) the demonstration on the initiation of vetiver handicraft making by 15 members of the Vetiver Group, Kok Prong Sub-District, Wichian Buri District, Phetchabun Province, and (3) Display of vetiver handicraft products for sale by Pat Pat Shop of the Chaipattana Foundation.

Preamble:

The Chaipattana Foundation has conducted His Majesty's project to promote and support the cultivation of vetiver for soil and water conservation through continuous development on the utilization of vetiver for handicraft making to achieve economic benefit of vetiver cultivation. It has requested the Textile Design 6 Branch of the Faculty of Architecture, Phra Chom Klao Chao Khun Thahan Lat Krabang Institute of Technology to provide support on the design and development of vetiver handicraft products for sale by the Pat Pat Shop in order to contribute to economic utilization of the community, based on His Majesty's initiatives.

The Textile Design 6 Branch of the Faculty of Architecture, Phra Chom Klao Chao Khun Thahan Lat Krabang Institute of Technology, in cooperation with Pat Pat Shop have agreed to manage such an activity through the learning of the course on design of textile products, together with the operation of research project on the development of the design of vetiver handicraft to make it a product in community's ecnomic development for the targeted group (i.e. vetiver group consisting of 25 villagers of Kok Prong Sub-District, Wichian Buri District, Phetchabun Province) to obtain the information and to disseminate the knowledge through various media in order to make them products for sale by the Pat Pat Shop.

The students of Textile Design 6 Branch will study and conduct research on the property and suitability in the utilization and the beauty of vetiver grass, the knowledge on the design of the yarn; the design of various textile patterns and to tie vetiver yarn into gooseberry-seed pattern; the design of vetiver handicraft products for the targeted group in order to develop a set of knowkedge in weaving and tieing gooseberry-seed pattern for the community.

Objectives:

1. To enable to targeted group to make use of vetiver leaves planted for soil and water conservation to produce prototype products, which are enable to contribute to economic development in the future.
2. To enable the students to learn the knowledge of textile and tieing gooseberry-seed pattern as the community's local wisdom.
3. To design and produce exemplinary products for the Pat Pat shop.
4. To provide the opportunity for the students to learn to work together with the targeted group.

(See photographs on pages 7-9)

Learning About Vetiver in Chiang Mai, Thailand*

In November 2014 over 50 people from all over Asia gathered in Chiang Mai for one of *LEAD Asia*'s Community of Practice (CoP) events. *LEAD Asia*, part of SIL International [1/] in Asia, serves ethnolinguistic communities throughout the region by providing a forum, including running events, for education and development practitioners to share resources and experiences together. At this specific event we gathered together to learn about environmental issues and how they relate to language, education and development.

LEAD Asia's vision: Communities in Asia are achieving their education and development goals, while sustaining and celebrating their unique ethnolinguistic identities.

Now why would an education and development-oriented organization that works primarily with minority language communities in Asia, be interested in the environment (and what's this got to do with vetiver anyway)? Environmental issues are now a prime concern for all development organizations and practitioners and for the communities they serve. From issues large and complex,

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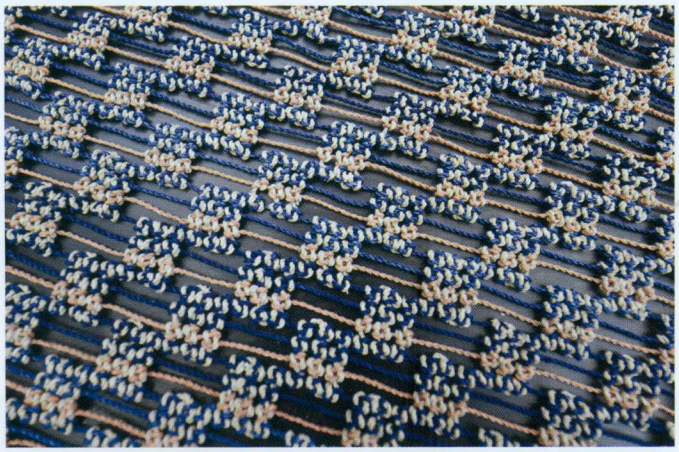
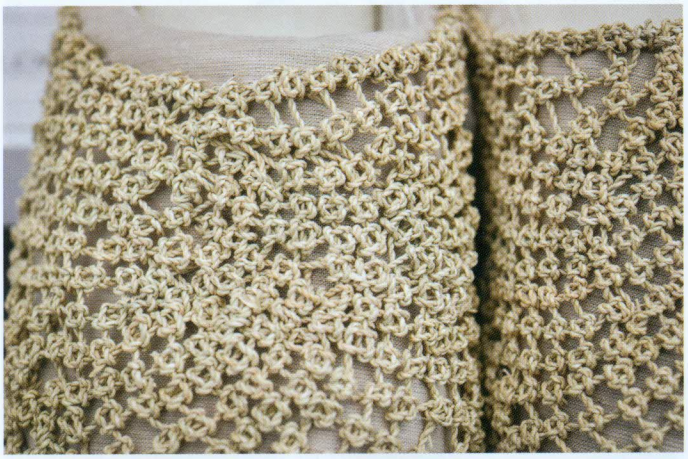
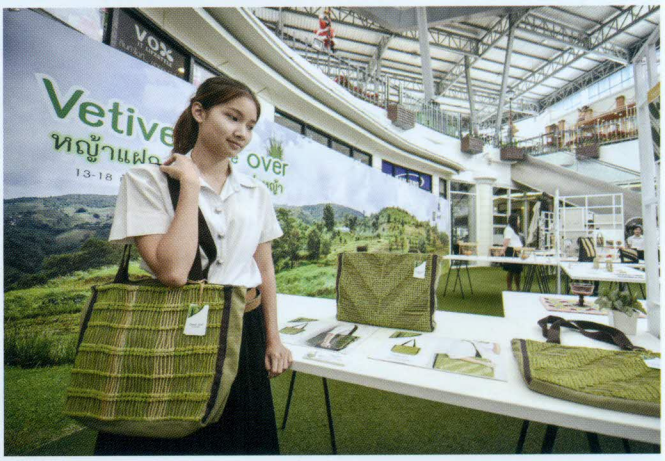
* By David S. Price, LEAD Asia Senior Environmental Consultant <david_price@sil.org>; <www.leadimpact.org>

[1/] SIL International is a faith-based nonprofit organization committed to serving language communities worldwide as they build capacity for sustainable language development. www.sil.org

Exhibition of Vetiver Handicraft and Vetiver Textile in Thailand








Vetiver make over
หญ้าแฝก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Vetiver make over
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Pictorial Report
Evaluation Work on the Utilization of Vetiver Grass in Thailand

The North: Chiang Rai and Chiang Mai Provinces during 19 – 21 February 2014

The Northeast: Nakhon Ratchasima and Surin Provinces during 5 – 7 March 2014

The lower North: Uthai Thani, Kamphaeng Phet and Tak Provinces during 19-21 March 2014








The Centre: Phetchaburi and Prachuap Khiri Khan Provinces during 29 April-1 May 2014

Planting vetiver to remediate Non Nae Creek, Phanom Sarakham, Thailand


Planting 1000 vetiver tillers to remediate the bank of Arroyo Sarandi River, Buenos Aires






such as climate change and its impacts, to plain, small and localized - but still complex - such as illegal logging in forested traditional lands, every community and city in Asia is being, and will increasingly be, impacted by problems that have their basis in the environment. Not only is our development work and advocacy impacted by environmental issues, the converse is also true - our development work has ramifications for the environment, good or bad, and that affects everything, including human health, livelihoods, land use, and even cultural identity.

During a long and rewarding career as a language development specialist in Indonesia I developed a strong interest in environmental and ecological sustainability and how it relates to development in minority language communities. I helped local communities there with mangrove restoration, small-scale native forest restoration, wastewater treatment, and land degradation issues. I had several years of experience using the Vetiver System in Papua, Indonesia, including for degraded land rehabilitation, riverbank stabilization, wastewater treatment, and, of course, for erosion control. In 2012, after I left Indonesia, I was asked to become *LEAD Asia*'s first Senior Environmental Consultant and after much planning we were ready to have our first community of practice event focusing on environmental concerns.

During our event in Chiang Mai several commonalities emerged - no matter where our participants came from they faced very similar environmental issues. Deforestation, climate changes, loss of traditional lands, and land degradation and erosion appear to be almost universal throughout Asia. For the latter it was natural to focus in on the Vetiver System - I felt it would be of immense value if we could introduce our participants to vetiver grass and its uses.

Of course, a lot of powerpoint slides and discussion can only take you so far and therefore we planned to take one day for a field trip so that participants could get a hands-on look at vetiver grass and see it in action. For several months before our event I had been talking with Suwanna Pasiri of the Office of the Royal Development Projects Board (ORDPB) in Thailand, and her team and mine had been working hard together to plan the field trip. Suwanna, a devoted Arsenal football fan, has long experience with vetiver and would be in the Vetiver Hall of Fame - if we had one. Suwanna and others, under the mandate of His Majesty, the King of Thailand, have studied and promoted vetiver throughout Thailand and neighboring Asian countries for many years.

Very generously, Suwanna's team brought some potted vetiver plants and slips to our event so that we were able to use these in the presentations and discussions in preparation for the field trip. The field trip itself consisted of visits to three sites. First was a tropical forest restoration project of FORRU (Forest Restoration and Research Unit of Chiang Mai University) at Ban Mae Sa Mai, and the third a visit to ECHO's Partners Farm in Mae Cho. In between we had the privilege of visiting the ORDPB's Vetiver Demonstration Site where we really saw vetiver in all its glory.

The ORDPB folk had prepared quite a reception for us and treated us like honored guests. We saw two very good presentations, including one by Dr. Narong Chomchalow who was in the area. Dr. Narong, who would also be in the Vetiver Hall of Fame, is a very eloquent and engaging speaker and talked about the history of vetiver in Thailand, a history that is entwined with his own. Then we were led around the grounds of the vetiver site where various applications of vetiver were being showcased. And finally, those participants who wanted vetiver slips to take home, where allowable, were able to take a small supply of starters.

One of the tremendous values of the ORDPB Vetiver Demonstration Farm is that it is research driven. Several areas are devoted to experiments investigating techniques of propagation, steep land stabilization, and control of sediment-laden runoff. Part of this research involves work with the shade tolerant *Chrysopogon nemoralis*, since one of the limitations of *C. zizanioides* is that it requires full sun to thrive. However, since *C. nemoralis* appears to not be sterile (it sets viable seed) there may be the risk of it being invasive and therefore extreme caution is warranted. ORDPB are doing more research on this.

And so it was an excellent opportunity to visit, but what of the outcomes for *LEAD* participants? Learning is useless if not applied, right? Well, our participants were extremely impressed with vetiver, its qualities and applications, and almost all were excited to apply the technology to pressing issues back home. Some participants from cold, mountain areas were

disappointed that vetiver does not handle seasonal freezing conditions and others may face challenges in obtaining the grass in their particular country. Fortunately, thanks to those who have gone before us, vetiver is widely available in most Asian countries. Already, our participants from at least one country have started moving forward, obtaining slips and breaking ground on their own vetiver nursery. As *LEAD Asia*'s Senior Environmental Consultant I think (and hope) I'm going to be very pleasantly busy helping people with vetiver projects for the next couple of years or so.

"Our context is very different from Thailand's, but we have learned a lot about vetiver, reforestation, and from ECHO Asia, and we will go from community to community to share these things", remarked a participant from Cambodia.

We were overwhelmed by the hospitality of Suwanna's team and I would like to express our gratitude to them for making this part of our event, and especially the field trip, so wonderfully successful and, I believe, productive for the future. The ORDPB is an impressive initiative and their Vetiver Demonstration Farm is exceptional in terms of showcasing vetiver applications and current research. Thank you Suwanna, Narong and our other new friends at ORDPB.

If you would like to know more about LEAD Asia and how we might be able to support you in your work in environmental sustainability, and especially with the Vetiver System, please contact me.

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Evaluation Work on the Utilization of Vetiver Grass in Thailand*

On 21 January 2014, the Working Group on the Evaluation of the Development and Promotion of the Utilization of Vetiver Grass According to the Royal Initiatives officially started to work with the Office of the Royal Development Projects Board (ORDPB) as secretariat. The main duty is to monitor the project implementation, problems, obstacles and outcomes, as well as the future plans for an effective implementation.

In the fiscal year 2014, the working group went to the fields five times to observe the implementation of ten agencies in two broad aspects. They are: (1) Study, experimentation and research works; (2) Promotion, dissemination and public relations works. The sites of observation were as follows:

(i) The South: Nakhon Si Thammarat and Songkhla Provinces during 11 – 13 February 2014
(ii) The North: Chiang Rai and Chiang Mai Provinces during 19 – 21 February 2014
(iii) The Northeast: Nakhon Ratchasima and Surin Provinces during 5 – 7 March 2014
(iv) The lower North: Uthai Thani, Kamphaeng Phet and Tak Provinces during 19 – 21 March 2014
(v) The Centre: Phetchaburi and Prachuap Khiri Khan Provinces during 29 April – 1 May 2014

The implementation results can be concluded as follows:

1. Study, Experimentation and Research Works: Most of the evaluation focused on the effectiveness of the utilization of vetiver grass for the conservation of soil and water, soil development, environmental restoration, and on the suitable vetiver varieties with the problems and the condition of the areas. The vetiver varieties that were typically grown were Prachuap Khiri Khan, Songkhla 3 and Sri Lanka.

Problems of the areas: The land suffered from erosion and the lack of fertility and productivity, and natural disasters such as floods and landslides.

Advantages of vetiver: Vetiver grass can enhance the soil's quality and prevent soil erosion

* By the Office of the Royal Develoment Projects Board, Bangkok, Thailand

to some extent. Moreover, its root can absorb toxic substances, for example those in the water until it can be usable again.

Problems and obstacles: It was found that most vetiver tended to die when shaded by the trees grown nearby as vetiver needs sunlight. In addition, most of the areas were deteriorated land, unfertile, filled with stones and laterite and unproductive. Regarding the use of vetiver grass as substitute materials, there were procedures which consume energy and high expenses. The other setbacks were the lack of vetiver tillers and water supply, and the misconception among the farmers that growing vetiver grass yields less benefit than growing other cash crops.

Recommendations from the Sub-committee on Academic, Monitoring and Evaluation: The successful utilization of vetiver grass, if achieved, should be promoted, disseminated and publicized. In this respect, it is important to identify whether there are any different outcomes between growing vetiver grass alone and intercropping vetiver grass with other crops.

2. Promotion, Dissemination and Public Relations Works: It was found that most agencies grew vetiver in agricultural areas for soil and water conservation, soil development and nourishment, and prevention of soil erosion through environmental rehabilitation and prevention of landslides in the disaster-prone areas. The vetiver varieties that were typically grown included Prachuap Khiri Khan, Songkhla 3, Surat Thani, Sri Lanka, Mai Huai Wai and Roi Et.

Problems of the areas: The problems found included lack of soil fertility, steep slopes resulting from soil erosion, continuous use of chemicals and pesticides in agriculture which made the soil deteriorate and unsuitable for agriculture, as well as lack of water for agriculture in the dry season.

Advantages of vetiver: After planting vetiver grass, the soil erosion reduced to some extent, the soil moisture increased to be suitable for agriculture, the produce yield increased when intercropping the plants with vetiver grass, and the farmers received supplementary incomes from selling bare-root vetiver slips and vetiver handicraft products.

Vetiver plantation was also promoted in schools. It was found that, beyond the aims of soil and water conservation as well as reduction of soil erosion in schools' areas, the activity enhanced unity, corporation and bond among teachers, students, janitors and parents. In addition, growing of vetiver grass was included in curriculum in the subject of agriculture. The lunch of the students was from the plants grown in the schools' agricultural plots together with vetiver grass. The income from selling of vetiver handicraft products was also put into the Welfare Fund for Lunch.

Problems and obstacles: Most farmers still did not see the importance of the utilization of vetiver grass due to the lack of knowledge and understanding about vetiver grass and the inadequate water for agriculture and care and maintenance of vetiver grass.

Recommendations from the Sub-committee on Promotion and Dissemination:

1. To reduce the use of plastic bags when distributed, vetiver grass should be propagated with bare-root slips.

2. To help prevent soil erosion, vetiver grass should be grown in rows alng the contour line with the interval of 50 cm. to 1 m. between the rows (depending on how steep the slope is) and 5 to 10 cm. between the plants. By 3 months, the vetiver will grow and fill the gaps to serve as a living wall which can effectively prevent soil erosion. In this regards, the appropriate period for growing vetiver grass is 1 month before the rainy season, which is between April – May in order to ensure its survival.

3. To be accepted by the farmers, there should be a more expansive extension work by promoting various means of vetiver grass' utilization.

4. To see a clearer result, there should be a comparative study on the fruits and vegetables yielded in terms of quality and quantity from the plots where the plants are grown with and without vetiver grass. In this connection, leguminous plants such as Sunnhemp should be grown to add more nutrients to the soil.

(See photographs on pages 10-13)

An Urban Wastewater Solution in Ghana Using African Vetiver Grass*

The world is witnessing a water quality crisis, mainly brought about by rapid population growth, industrialization, food production practices and poor water use strate-gies. As population increases, so does wastewater output. In developing countries, about 90 per cent of all wastewater is discharged untreated directly into rivers, lakes and oceans.

The impact of wastewater on the environment and human health is not only striking but frightening. A report by the United Nations Environment Programme (UNEP) and UN-HABITAT in partnership with members of UN Water indicates that two million tons of sewage, industrial and agricultural waste are discharged into the world's waterways and at least 1.8 million children under five-years-old die as a result every year. That is, one child lost every 20 seconds due to water related diseases.

Inadequate infrastructure and lack of financial resources are largely to blame for the wastewater menaces that plague most developing countries, especially their cities. In these countries, septic tanks receive the faecal waste of most urban dwellers, while other household liquid wastes are directed into the nearest drains.

Because drainage system costs are frequently prohibitive, the majority of urban drains are open, lending themselves to misuse and sometimes serving as defecation points for households without adequate sanitation facilities. Industrial wastewater -- from breweries and other sources such as the textile, mining, chemical and pharmaceutical industries -- is usually discharged into these open drains or into water bodies without any pre-treatment, posing health hazards.

The Quest for a Cost Effective Technology

Managing wastewater in an efficient and sustainable way calls for a multifaceted approach. Various measures including behavioural change approaches towards combatting water pollution and the use of appropriate infrastructure, technologies and techniques will help reduce the impact of wastewater on the environment and on humankind.

The quest for an immediate approach to wastewater treatment in developing countries has spurred research within the scientific community. Among that research is a project being carried out by the United Nations University Institute for Natural Resources in Africa (UNU-INRA) in partnership with Ebonyi State University in Nigeria.

The project is assessing the potential of an African vetiver grass species, *Chrysopogon nigritana*, in treating industrial effluents and wastewater from domestic origins, which have been major sources of contamination. In Africa wastewater is increasingly becoming important resource for various uses including irrigation in urban and peri-urban agriculture. This wastewater is often high in toxic heavy metals including arsenic, cadmium and manganese as well as components of nutrient pollution such as phosphates and nitrates.

The general findings of this vetiver project reveal that *Chrysopogon nigritana* can reduce these contaminants in industrial effluents and domestic wastewater. For example, in one case, samples were taken of leachate from a dumpsite and treated with *Chrysopogon nigritana* for seven days. Laboratory analysis of the chemical properties of the treated leachate indicated that phosphate, which was at a pre-treatment level of 92.9, was reduced to 19.71 mg l^{-1}, while Chemical Oxygen Demand (COD) dropped from 151.78 to 50.57 mg l^{-1}. These levels are far below the United States Environmental Protection Agency's (USEPA) permissible limits of 50 and 75 mg l^{-1} for each of these respective chemical properties in water.

Similarly, laboratory results showed that arsenic and cadmium properties, which were both initially at pre-treatment levels of 0.2mg l^{-1}, were completely removed from sample effluents taken from a fertilizer company after a six-day vetiver grass treatment. The absence of these chemical

properties after treating the effluents with the vetiver grass is very satisfactory because the World Health Organisation / Food and Agriculture Organisation's (WHO/FAO) acceptable levels for arsenic and cadmium in water are 0.10mg $l^{-1}$and 0.005mg l^{-1}, respectively.

Additionally, analysis of a sample slaughter house wastewater treated for seven days by the vetiver showed about 88 percent reduction in manganese (from 1.03 mg l^{-1} to 0.12 mg l^{-1}) -- a reduction well below the WHO/FAO's safety standard of 0.20 mg l^{-1} for manganese in water.

Dr. Effiom Oku, Senior Research Fellow for Land and Water Resources at UNU-INRA and the research project's manager explains that, the results are significant and offer many developing countries, including those in Africa, a unique window of opportunity for reducing the impact of wastewater on human health. Dr. Oku noted that heavy metals such as arsenic can cause cancer of the skin, lungs, liver and bladder and exposure to high levels of metals like cadmium can severely damage these organs and ultimately cause death. "Irrigation of edible crops with untreated wastewater can result in the transmission of various infections including intestinal nematode and bacterial infections for both the consumer and the farmer as a result of the heavy metals in the wastewater, and the ability of the African vetiver species, *Chrysopogon nigritana*, in treating these domestic and industrial contaminated liquids will help reduce the health implications of consuming these crops among consumers," stated Dr Oku. He added that the use of untreated wastewater for crop irrigation affects not only human health but that cattle grazing on pastures irrigated this way can become heavily infested with the larval stage of the tapeworm *(Taenia saginata).*

Applying Vetiver Technology

In explaining how the vetiver technology works, Dr. Oku reiterated that the vetiver grass is cost-effective and highlighted simple ways to treat wastewater with the grass:

- After growing in soil for about 12 weeks, the mature vetiver grass can be dug up and separated into individual plants.
- The roots are then trimmed and the shoots are pruned to about 15-20 centimetres.
- The grass is then transferred to a "floater"-- a planting device that will allow the grass to float on the surface of water. The water has to be supplemented with nutrients such as fertiliser, cow dung or poultry waste (hydroponic agriculture).
- The plants are allowed to grow in their floaters for another 8-12 weeks before being transferred with their floaters to the wastewater in need of treatment.
- The plants are then left in the wastewater to grow and the roots and leaves are periodically pruned.

Dr Oku explained that once the vetiver plants are put in the wastewater, the grass will start removing the contaminants in the water through the roots to the leaves, hence the need to prune the roots and the leaves regularly. He added that, "this is a green technology that leaves behind no carbon footprint since it does not use conventional energy such as oil, gas or coal".

Dr Elias T. Ayuk, the Director of UNU-INRA, also speaking on the relevance of the research, acknowledged that future demand for water cannot be met unless wastewater management is revolutionized. He added that in its role as a natural resources management think tank of the United Nations and its member states in Africa, UNU-INRA conducts studies such as this one to help inform policy formulation and implementation. Dr Ayuk said findings from these studies will help direct efforts towards the judicious use of natural resources for development.

Indeed, the development of many countries will depend on investment in sanitation and water treatment. As revealed in the UNEP report, every dollar invested in safe water and sanitation has a payback ranging from US$3 to US$34 depending on the region and the technology deployed. It has therefore become imperative to meet wastewater management challenges with cheaper technologies like the vetiver grass option to ensure a healthy environment and sustainable development.

Remediation of the Bank of Arroyo Sarandi River in Buenos Aires with Vetiver*

The Ombudsman of the Avellaneda City, Buenos Aires, Argentina, has launched a remedial project with students and teachers from the Simon Bolivar School.

On Wednesday, October 22, 2014 the Ombudsman of Avellaneda City and students of Simon Bolivar School planted 1,000 tillers of vetiver to remediate a contaminated site of about 100m long on the banks of the Arroyo Sarandi River. This work was performed by the students of Simon Bolivar School with teachers leading the project. The development of the project is being supervised by Sergio Ferrari, an environmental engineer, and his crew, who from the start of the works with the Office of the Ombudsman, as well as other projects being initiated by the Ombudsman.

Soil samples from the bank of Arroyo Sarandi River will be analyzed to determine the degree of contamination. That will be the baseline against which the obtained results will be compared. This will be observed as improvement of the soil on the bank of the Arroyo Sarandi River by the Vetiver System. The students, who also received training, conduct monthly visits to Arroyo Sarandi River, to assess the growth of plants and to perform maintenance and care of the Vetiver System.

(See photographs on page 14)

*By El Defensor del Pueblo de Avellaneda, Sebastián Vinagre, lanzó el 1° Proyecto de Remediación con alumnos y docentes de la Escuela Simón Bolívar

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