The ability of Vetiver Grass to act as a primary purifier of waste water; an answer to low cost sanitation and fresh water pollution.

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Abstract:

Phytoremediation is the term given to the process of treating waste water through a hydroponic system which incorporates certain plant species as the filtration agent.
The aim of the project is to illustrate the potential of certain plant species to act as primary purifiers of polluted water.
Vetiver grass was chosen as the preferred plant species due to its known efficiency, low cost, ease of propagation and availability.
Vetiver (*Vetiveria zizanioides*), originates in southern India and has been used extensively all over the world for stabilizing vegetation and as the solution to the ever-increasing problems of soil erosion, wind erosion and degradation of the landscape.
Recently, the focus has shifted toward the plants' ability to absorb phosphates, nitrates, heavy metals (which are known to be toxic in high concentrations) and cholera and dysentery causing bacteria (e-coli).
The Vetiver grass was subjected to three different environments:

- Constant inflow of raw effluent/waste to vetiver grown in hydroponic conditions on a raft
- Fixed volume of processed waste to vetiver grown in hydroponic conditions also on a raft
- Open ground planting (as a control)

The absorption rates of indicator chemicals and nutrients were measured and compared for each of the three environments.
The results illustrated that vetiver grass is an efficient biological means of primary filtration and can be used as a low-cost primary filter of water run-off in poorer areas- where it is not treated and discharged into natural water courses.

Introduction:

With a rise in global populations, especially in 3rd world and developing countries, housing densities have significantly increased. Much of this housing is inadequately serviced by sewer systems; this waste will join surface water run-off and cause it to become highly contaminated and discharge into natural water courses.
It is now accepted that fresh water supply is under threat throughout the world. This project focuses on the ability of the vetiver grass system to absorb heavy metals and therefore its suitability as a primary filter medium for treatment of waste water (phytoremedial technology).
Many harmful elements and disease causing bacteria are present in sewage water, thus, with a lack of proper drainage, this sewage will mix with drain and rain water and flow toward low points which tend to be dams and lakes. It goes without saying that ultimately, this water will reach the sea and cause significant damage on route.
The basic Vetiver Grass Technology or Vetiver System comprises a dense vetiver grass (*Vetiveria zizanioides)* hedgerow that is planted across the slope of the land or embankment. The hedgerow traps sediments, spreads out rain-water runoff, and provides through its roots significant reinforcement to the soil, (Grimshaw, 1993).
The Vetiver system was first developed by the World Bank for soil and water conservation in India in the 1980's, (Troung, 1998).
By introducing vetiver and educating less-privileged countries to its importance, the World Bank had raised awareness to this 'wonder' plant. Vetiver has been used in many countries to solve the problems of erosion and loss of arable lands due to erosion.
Vetiver grass originates in India and West Africa. The vetiver species used in the project is from south India (*Vetiveria zizanioides*) and is non-invasive as it has sterile seeds. The only way for it to spread is vegetative reproduction. The African genotype is known as *Vetiveria nigritana* which is also considered non-invasive but is not as effective as its Indian cousin.
Vetiver has many applications which range from mine dump rehabilitation, slope stabilization, wind barriers, water barriers, seepage control, cattle fodder, production of essential oils and fabric for rope and garments, and water treatment, which is the main idea behind this project.

Vetiver grass is effective in all its applications because it has a very large and deep penetrating root system that can grow to about 4 meters. The tensile strength of vetiver grass is about one eighth of mild steel, which allows it to be so resistant to environmental influences. The maximum tensile strength of vetiver grass (*Vetiveria zizanioides*) reaches 75mpa, whereas Bermuda grass (*Cynodon dactylon*) reaches 13.45mpa, (Cheng, et al, 2003). The plant produces stiff erect leaves which can be used as feed for livestock as well as a mulch cover for the hydro seeding industry.
The vetiver system (VS) has been used in many countries and has produced positive results in all cases where applied, it has no apparent negative impacts on the environment.

The majority of studies relating to vetiver, which have been conducted, were associated with slope stabilization, gully erosion control, revegetation of bare land and also mine dump rehabilitation.
Only a hand-full of studies (P. Truong, in particular) have been conducted regarding vetiver's ability to reduce pollutants and act as a primary purifier for sewage effluent under hydroponic conditions.

Vetiver grass has a high tolerance to harsh conditions and harmful soils. Vetiver can be used in a variety of different ways to treat sub- standard water and effluent. The high rate of absorption is ideal for this study. With those facts in mind, current processes of water recycling and sewage treatment could be explored using vetiver as an alternative or as a solution.
Application of the Vetiver System (VS) for wastewater treatment is a new and innovative phytoremedial technology developed in Queensland by the Department of Natural Resources and Mines, NRM, (Truong and Hart, 2001).

This project fits in well to studies that have already been done to date. It can be used as one of the 'building blocks' for future sanitation and waste management. Previous studies have been conducted by Dr Paul Truong (2001), using vetiver on sloping wetlands where the contaminated or polluted water is channeled through these vetiver beds which are arranged along the contours of the slope. The advantage of this is that the roots and leaves form a strong barrier that reduces flow velocity and causes deposition of heavier particles. Uptake of bacteria, heavy metals and nutrients will occur at any depth between the surface to about 4 meters.
My project can be used as re-inforcement for previous studies and as a basis for pre-treating polluted water.
Water reclamation works are costly and require constant supervision and monitoring; typical purification methods incorporate mechanical and chemical processes which are labor intensive, require large amounts of energy (non-renewable) resources, and are costly (Picture 21). Whereas, vetiver, on the other hand, is a biological purifier and a renewable resource which can be used in other applications when no longer required for Phytoremediation purposes. The vetiver bush could be divided up into individual plants (slips) and propagated for slope stabilization and seepage control.
If someone found a low-cost alternative for poorer or underdeveloped areas, it would solve a lot of problems regarding sanitation and obviously fresh water supply. The point is to prevent untreated water from entering the environment. This technology could also be used in areas that are really remote and don't receive any formal sanitation, game reserves for example.
The projects aim is to illustrate Vetiver's ability to remove Heavy metals from contaminated water by comparing the amount of heavy metals absorbed by vetiver roots under hydroponic conditions and those grown in soil.

Floating polystyrene rafts were designed and constructed which allowed the vetiver's roots to be fully immersed in the water/effluent. The reason I chose to float the vetiver on rafts was because the uptake of pollutants would be a lot more efficient and effective as there is no soil to hinder its path. The vetiver would grow in polluted sewage water for 6 months with frequent monitoring.

This project is related to waste water and the best way to treat it before it reaches our fresh water system. It also provides a guide for poorer areas as how best to deal with their waste and with stagnant, polluted pools that would accumulate over time and after rain. Vetiver rafts and planted vetiver wetlands are the future of affordable, acceptable waste water treatment for everyone regardless of income status.

This study is important because it creates awareness toward the problem of sub-standard sanitation and it provides a framework for the future. This study will be used as a baseline of knowledge for a master's project in the future. This study was done in three steps: the first step was to acquire the vetiver and get them growing in the green house at NMMU-botany department. The second step would involve building of the rafts, placement of the vetiver onto the raft and flotation of the raft itself in the sewage water. The last step would be constant monitoring and analysis of the vetiver after about 6 months.

Methodology:

Once the topic of the project was decided, preparations needed to begin as soon as possible. Like many things in life, growth and results take time.
The first and most important aspect was to procure the vetiver shoots (Picture 1) which were donated by Hydromulch (Bapsfontein farm). The vetiver plants were couriered to Port Elizabeth.
While waiting for the arrival of the vetiver shoots, potting soil, small potting bags and fertilizer (super phosphate or 2:3:4) was purchased. The soil and fertilizer was mixed together to make a very nutrient- rich substrate, into which the young plants would be placed to grow for 3 months (Picture 2). Once all 300 shoots were planted into bags (making sure to bury the roots only), they were moved into the green house at Nelson Mandela university.
The plants were monitored and watered every second day, for three months (Picture 3 & 4).
The humidity of the green house remained relatively high for the duration of the study. This is one of the reasons why the plants' initial growth was so rapid.
Rafts were constructed using 3 sheets of polystyrene, which were previously purchased. The dimensions of the rafts (polystyrene sheets) were 2m ^{2} and 8 cms thick. An average of 90 holes was burnt into each raft (Picture 5, 6 & 7). These holes would eventually house the crown of the plant.
In order to maintain the structural integrity of the raft, 10m^2 of plastic meshing was ordered. This would enclose the entire raft once all the vetiver plants had been placed into their individual holes. This was very important because: in hydroponic conditions, (especially sewage water) materials (including polystyrene) break down very fast.
Securing the vetiver plants onto the raft began as soon as they looked healthy and once leaf development had begun.
The plants were removed from their bags and inserted in from the bottom of the raft, making sure not to damage the roots. Once all of the vetiver plants were fixed in position, the raft was wrapped with the plastic mesh, sewing the edges as one progressed. This created a strong outer layer preventing the plants from falling into the sewage water where they would be floated, plus it provided something to grab and raise the raft from the water for monitoring.
The study area was provided by the Cape Receife Water Reclamation Works. The original study area was an unused settling pond of about 8 cubic meters (Picture 8). This area was perfect for the study until it ran dry due to lack of use and maintenance. The plants were moved to a larger pond which was about 50m^2 (Picture 9). This was ideal as it was only necessary to measure the plants ability to absorb certain substances (heavy metals & important elements) that would otherwise be harmful to the surrounding area. The plants were left in a pond which was used by the water works as a storage tank for certain times of the year when sewage recharge is excessively large, normally holiday times (Picture 10 & 11).

A smaller experiment was run simultaneously to this one. Here a large container was used, it was filled with processed or semi-treated sewage water and a scaled down raft (containing 6 vetiver plants) was floated in it. This gave a better indication of the waters' color change; it also allowed a controlled experiment to be run where there was no recharge (Picture 12 & 13).
The largest experiment did receive an excessive amount of untreated sewage over the Christmas period. I will refer to this as the raw sewage experiment.
The raft was left in the storage pond for 6 months. This provided enough time to find a qualified professional soil scientist (Dr J A J Van Vuuren) to interpret the results of the root and leaf analyses which measured accumulated concentrations of nutrients and heavy metals. Soil analysis was Carried Out by SGS laboratory in Midrand.
Once the 6 months had passed, the plants were removed from the rafts, wrapped up and couriered to Johannesburg for analysis (Picture 20). A control plant was grown for the same period in soil at the Hydromulch premises. By comparing the plants that were grown in soil, in raw sewage water and in processed sewage water, a deduction on how effective this method of sewage pre-treatment could be made.

Reference pictures:

Picture 1: **Picture 2:**

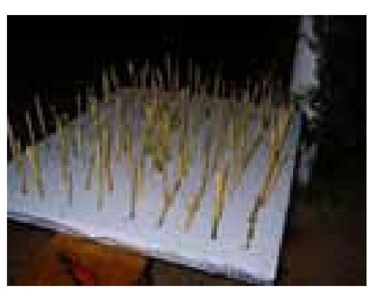
Acquiring and planting vetiver slips in preparation of project

Picture 3: **Picture 4:**

Growth of Vetiver in NMMU greenhouse over period of 3 months

Picture 5: **Picture 6:** **Picture 7:**

Construction of hydroponic rafts designed for flotation of Vetiver plants.



Picture 8:
Initial study area – abandoned.

Picture 9:
Actual study area - project

Picture 10:
Raft grown in raw effluent.

Picture 11:
Monitoring and checking root lengths

Picture 12:
Processed effluent container

Picture 13:
Root length at beginning of project

Picture 14: **Picture 15:**

Raw effluent vetiver root length after 3 months

Picture 16: **Picture 17:**

Vetiver after 6 months in the processed effluent

Picture 18: **Picture 19:**

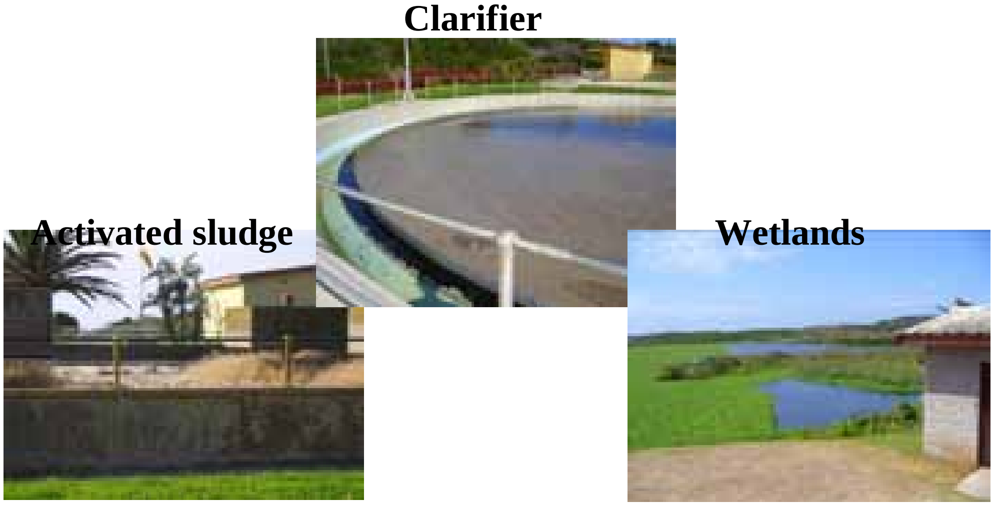
Vetiver Progress after 6 months in raw Effluent

Picture 20:

Comparison of Vetiver roots and leaves after 6 months under hydroponic conditions

Picture 21:

Conventional methods of waste water treatment



Results:

Figure 1: Root Analysis- Uptake of Elements

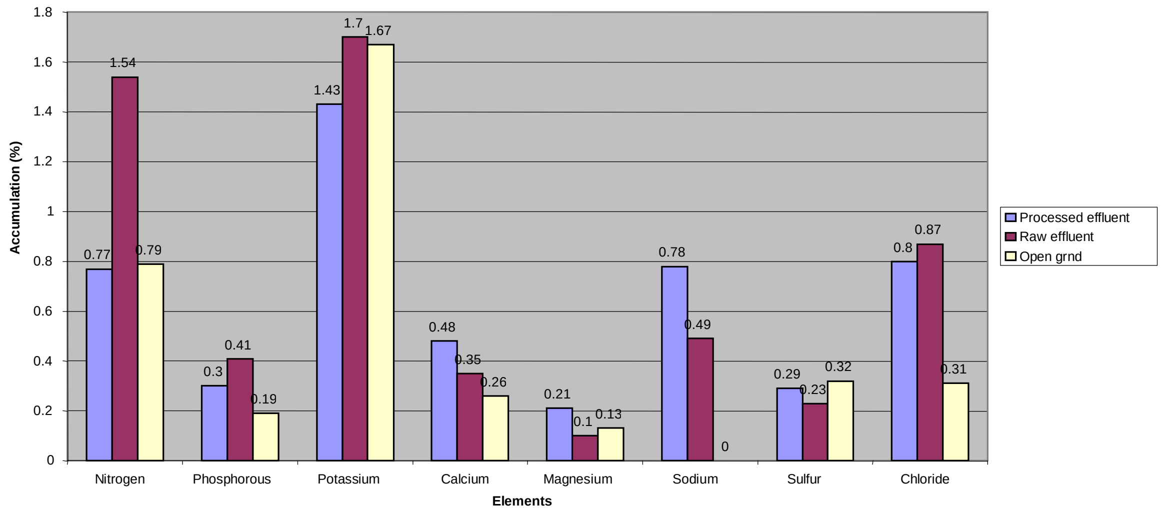
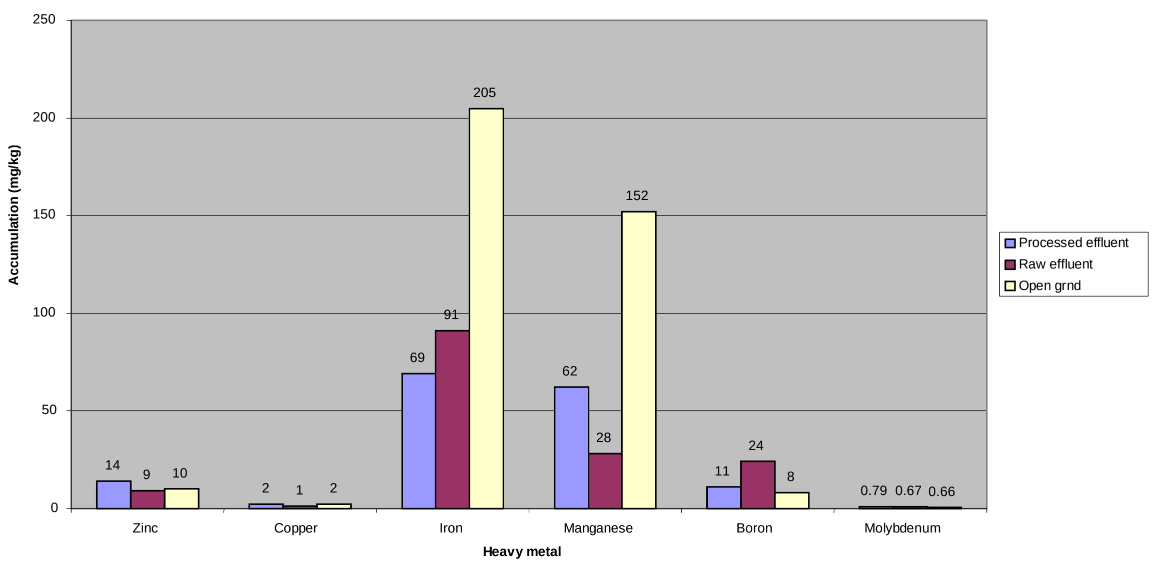


Figure 1 shows the accumulation of elements by the vetiver roots. It is clear that the absorption of Nitrogen, Phosphorous, Potassium and chlorides is at its greatest when comparing the raw effluent to the others. In the case of the processed effluent, Calcium, magnesium and sodium are absorbed the most. The absorption of sulfur from open ground plants is greatest. This may be because sulfur takes longer to absorb, which suits the open ground plants as the recharge rate of water is a lot slower than the hydroponic state

Figure 2: Root Analysis- Heavy Metal Uptake



The main trend in figure 2 is the high Iron and Manganese (density: 7.86 & 7.43 g/cm³ respectively) uptake from open ground vetiver. When looking at figure 4; we notice that open-ground vetiver has a total accumulation of iron that is lower than the raw effluent vetiver. Therefore the optimal environment for uptake of these elements would be a combination of these. Slow moving effluent into the storage pond with raft-grown vetiver and over open ground vetiver, after that, the remaining effluent or biologically treated sewage can flow into a large vetiver plantation. Figures for uptake of iron and manganese are low for the processed and raw effluent, this could be due to their high density values, but total accumulation results are promising. The Boron uptake from raw effluent is twice as high as the other two environments; this could be due to the fact that boron was more readily available in the raw effluent. Activated sludge and clarifying stage remove most of the heavy metals. The other heavy metals seem to be taken up at roughly the same rate.

Figure 3: Leaf Analysis- Elements

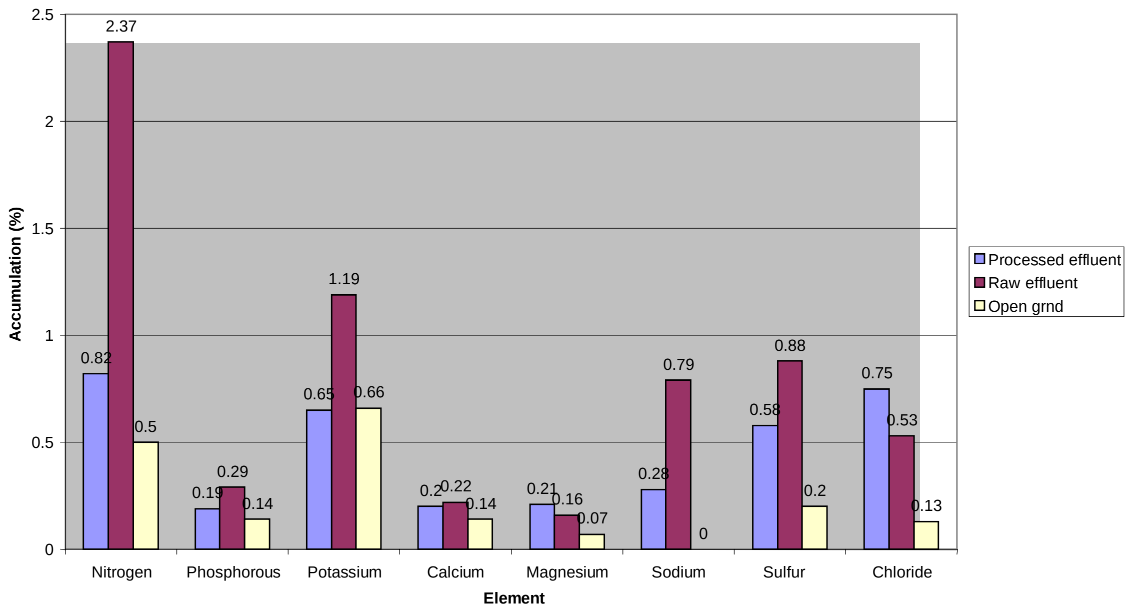
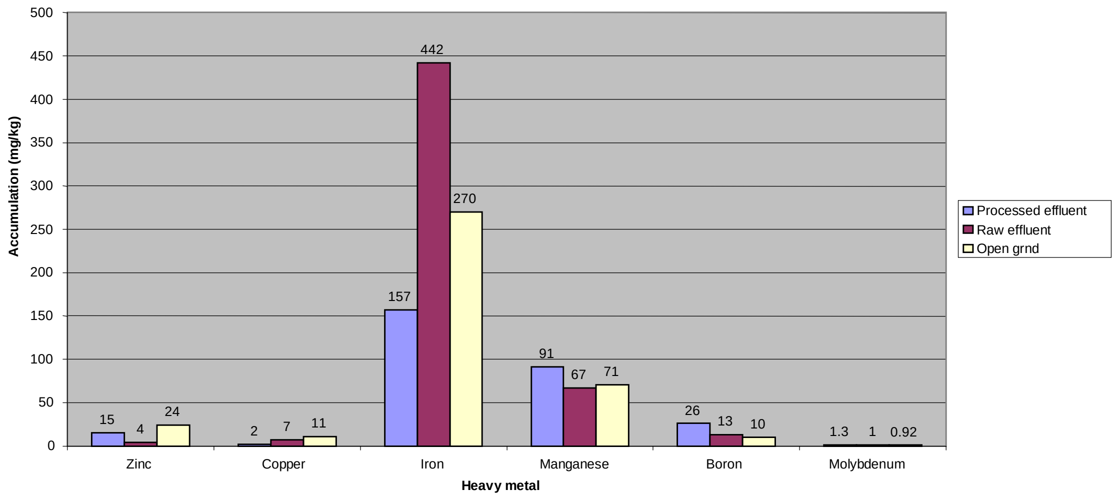


Figure 3 illustrates how nutrients are stored and incorporated into the lush leaves. There will be a greater concentration of certain nutrients in the leaves and the remaining elements will be stored in the root system. With the exception of chlorides, raw effluent is seen as the best environment for nutrient uptake. Chlorides are absorbed at a greater rate than from the processed effluent and open ground. With a nitrogen accumulation of 2.37%, the Vetiver showed promising results when considering the environment in which the nutrients were absorbed.

Figure 4: Leaf Analysis- Heavy Metals



When comparing figure 2 and figure 4, we notice that iron is absorbed by the roots more effectively from the open ground than from the raw effluent, but it is apparent that the storage of iron in the leaves of the raw effluent vetiver is far greater than that of the open ground.

Figure 4 also shows that iron absorption from the processed effluent is a lot lower than that of the raw effluent and open ground. This again could be due to the fact that this effluent has passed through 2 cleansing processes, thus arriving at the pond with far fewer nutrients and heavy metals

Figure 5: Total Accumulation by Plant, Elements

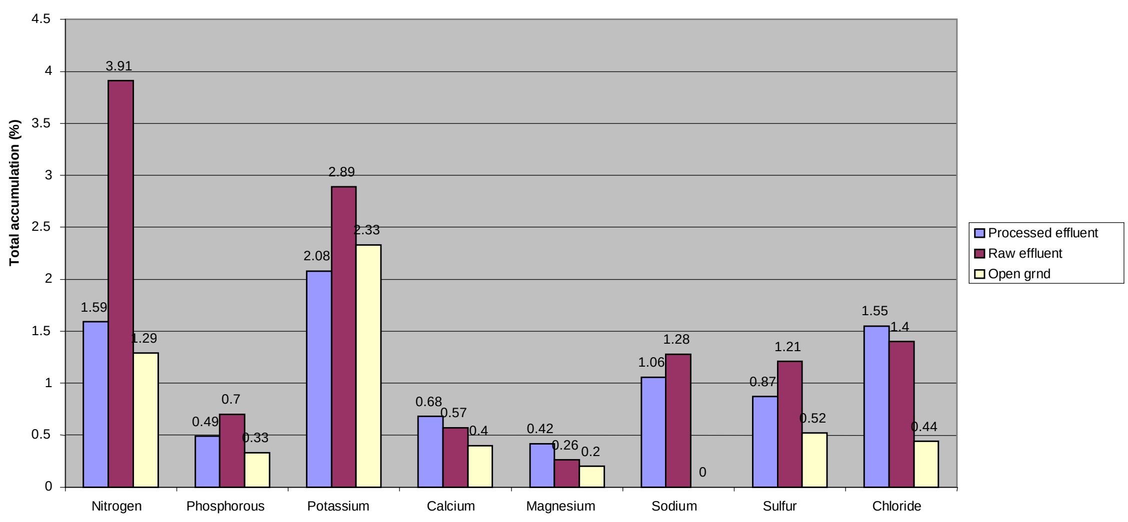


Figure 5 clearly shows how effective vetiver is at extracting nutrients from sewage effluent, thus rendering it safe to be released back into the environment. One trend that appeared is that nutrient uptake from the raw sewage was significantly greater than that of the processed effluent and open ground control. Calcium, magnesium and chlorides were absorbed best from the processed effluent. This graph clearly proves that vetiver grown hydroponically is far more effective at reducing pollutants in effluent than the vetiver grown on open ground.

Figure 6: Total Accumulation by Plant, Heavy Metals

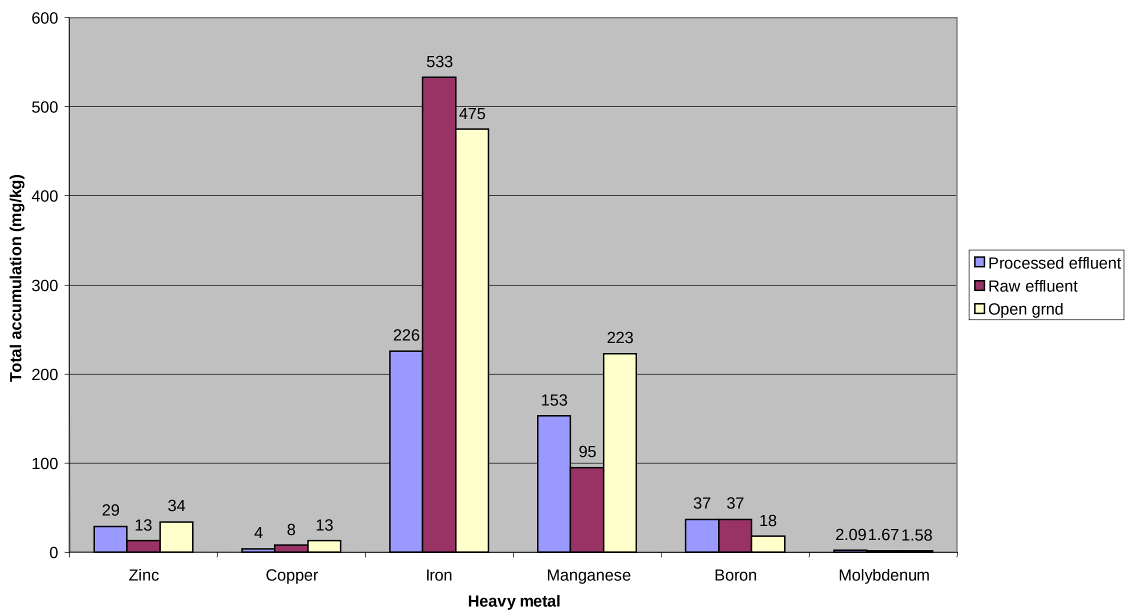


Figure 6 illustrates how efficient vetiver grass is at extracting harmful heavy metals like iron and manganese. The vetiver grown on open ground was especially effective at removing and storing manganese, which would otherwise end up in the fresh water system. A Figure of 95mg/kg of manganese absorbed by raw effluent vetiver was lower than the processed and open ground vetiver of 153 mg/kg and 223 mg/kg respectively. This could be attributed to the fact that manganese gets absorbed at a slower rate, therefore the raw effluent absorption rates will be lower due to the occasional recharge of the raw sewage.

Discussion:

As discussed in the abstract and introduction, Vetiver is a 'miracle plant', which has numerous good characteristics and no apparent negative ones.

Low cost, self sustaining sanitation and water recycling is a topic that should interest everyone and needs to be applied in less developed countries. This paper is a testament to the effectiveness of vetiver as a phytoremedial solution.

The project illustrates that Vetiver is effective at reducing toxicity of certain elements and heavy metals. Surely if no formal sanitation exists in an area, it would have positive effects to use Vetiver as the solution. The problem arises when sewage and surface run-off enter the fresh water system directly. It has been Shown that vetiver is highly capable of reducing e-coli bacterial counts by up to 97 % after only 14 days, it also showed that vetiver reduced the chemical oxygen demand (COD) by 63 % after 14 days of hydroponic treatment, (Truong, 2003). The fact that vetiver reduces disease causing bacteria should be reason enough to consider it as an environmental solution, in addition: no harm can be caused by testing it in the environment, as greater harm is occurring by doing nothing.

My proposal, to all those with sanitation issues, is to develop an area where Vetiver is concentrated and utilize it for reprocessing contaminated water.

As indicated by Truong and Ash, (2003) in their study of water quality improvement, vetiver is ideally suitable for treating contaminated and polluted wastewater from industries as well as domestic discharge.

Vetiver, as a phytoremedial solution, has not been researched extensively in South Africa but countries such as Australia and Thailand have conducted trials and analyses; expectations and results were exceeded in all cases.

In the same paper by Truong and Ash, (2003) they show how vetiver can be used to reduce the volume and improve water quality before the effluent discharges to the natural wetlands. The effluent is being treated first in the effluent storage pond by floating Vetiver rafts and then passing through a Vetiver grass contoured wetland constructed on 3 hectares of land.

My paper is in the same light, but the main theme of mine was a more in-depth study of vetiver' absorption of various different elements, with heavy metals being the main focus. Certain elements in high concentration are potentially harmful to man, animal and environment. Vetiver has the ability to absorb these and store them at these high concentrations.

Paul Truong illustrated that Vetiver can absorb certain toxic heavy metals and actually store them in the root system, thus rendering it safe for livestock fodder and in accordance with relevant environmental agencies specifications.

The project has illustrated how dynamic and versatile vetiver is at reducing elements and nutrients from raw and processed effluent. It is my intention to conduct further tests for a greater understanding of the Vetiver plant:

What would need to be done is survey the topography of the possible study area. By doing this, the high and low points can be established and a system can be put in place. Once you have found an area with a slope of anything more than 2 % gradient and less than 10% slope, you can start the trial. Sewage and surface run-off would obviously need to be concentrated into one main channel. This channel will need to end in numerous wide shallow ponds (< 1.5 m deep). Vetiver rafts would be placed here for the initial stage of treatment (Pictures 14 – 19).

The reason for this is that photosynthesis is most effective at this depth and the process will kill off certain harmful anaerobic bacteria which survive in water with low oxygen content. Many elements would be absorbed in this stage before moving onto phase 2. Contour planting of vetiver in numerous rows would prevent the sewage from rushing by. The rows will act as velocity suppressors, thus causing heavier particles to settle out and to be absorbed at a slower rate. The density of different elements, will obviously affect the rate at which they are absorbed, Vetiver will absorb these down to a depth of about 3 meters. Once the sewage effluent has passed through phase 2, the majority of harmful nutrients would have been removed. The final stage would be to direct the remaining treated effluent into a wetland system, where hydrophilic plants such as *typha* and *scirpus* thrive. This water could be used for irrigation of fields, crops and even golf courses. At this point, the water/recycled effluent would now be safe to rejoin the environment with a great reduction of pollutants, heavy metals, disease causing bacteria and algae causing nutrients such as nitrogen and phosphates. Efficacy of system will be established by comparing inflow water to outflow water. Substitution of high tech materials (polystyrene rafts and plastic netting) for natural ones such as bamboo rafts and braided grass netting could be done in poorer areas.

Conclusion:

The ability of Vetiver grass (*Vetiveria zizanioides*) to absorb harmful elements, bacteria and nutrients should be of great concern to all, because fresh water and effective sanitation are directly related. In Rural or poorer areas, sub-standard sanitation will directly influence the water quality at lower areas due to the forces of gravity. Ultimately, water and sewage will flow into the valleys of the area, and create pools. This standing water/sewage will start to infiltrate through the soil and eventually join fresh under-ground water.

The point I have proven in this paper, given that; Sewage, wherever you may live, needs to be recycled. This can occur by means of expensive sewage work systems or by natural biological purification. By looking at the quantities in the results, you can clearly see the amount of elements being absorbed was high, which would mean that the effluent was heavily loaded with these nutrients and the Vetiver still thrived where most other plants would die.

- The Vetiver absorbed many nutrients and heavy metals from the sewage, which could otherwise be hazardous to fresh water, man and ultimately, the environment.

With this in mind, it could be used as low-cost biological solution to this environmental hazard and health risk associated with bad or non existent sanitation. Water borne bacteria such as e-coli are common in sewage water and are the causes of many illnesses in less developed areas. Vetiver has the ability to extract and absorb certain bacteria, nutrients such as Nitrogen and phosphorous (which cause blue-green algae infestations) and heavy metals which are toxic in high concentrations.

Studies regarding Vetiver as a biological primary purifier have been conducted by few, with Dr P.Troung at the forefront.
None have been conducted in South Africa regarding Vetivers' ability to recycle waste water. Incorporating the concepts of certain studies by Dr Truong; where he created a sloping contour plantation of Vetiver as the second phase of the sewage treatment. These beds would be fed by the hydroponic treatment ponds (my study). After which, this water can be used for irrigation of golf courses and sports fields. Or the water could flow into a wetland where hydrophilic plants are found. Creating bird 'hot spots' is just an added bonus.

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