JOURNALOS

Volume 2, No. 5, December 2008

ISSN: 219 318 11

JASRI

Journalos of Advanced Scientific Research and Innovation

Germany, 2008

Physical and mechanical behaviour of mild steel under a CO_2 laser

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Abstract

In this paper, we investigate the physical and mechanical behavior of mild steel when machined using a CO_2 laser. First, some of the etched mild steel specimens are spray painted and dried. A continuous wave (cw) CO_2 laser beam with an estimated power of 35 Watts is then focused on both the painted and unpainted specimens for a wide range of exposure times. The machinability of the painted and unpainted specimens is observed. Both sets of specimens are then checked for any microstructural changes. It was clear that the unpainted specimens had no visible marks or microstructural changes even after the longest exposure of 1000 seconds. However, it was observed that exposure of the material to the beam had effects on the microstructure of the painted specimens even with as little exposure time as 30 seconds.

Keywords

Keywords: CO_2 laser, microstructure, paint removal, physical and mechanical properties, underlying material.

I. INTRODUCTION

LASERS are employed in a wide range of applications such as in cutting, marking, drilling, heat treatment, cleaning of surfaces and paint removal. This is due to the many benefits associated with the laser technology in terms of geometrical and dimensional accuracy which have proven to be difficult and expensive with conventional machining processes. Generally, metals are not good candidates of laser machining due to their high thermal conductivity and high reflectivity to the infra-red (IR) energy from a CO_2 laser. Painting of metallic surfaces has been used as a way of improving the absorptivity to the CO_2 laser radiation to allow easy laser machining. Physical properties of metals such as thermal conductivity and material viscosity influence quality, productivity, profitability and safety of laser cutting operation
[1].

For a particular material, a minimum amount of energy has to be absorbed for the material to be ablated by the laser beam. This absorbed radiation is converted to energy that raises the temperature of the substrate. The input of energy or energy deposition process from a laser beam into the near surface regions of a solid involves electronic excitation and de-excitation within an extremely short period of time [2]–[4]. This means that laser-matter interaction within the near-surface region achieves extreme heating and cooling rates in the range of 10^3 - 10^{10} K/s, while the total deposited

energy (typically, 0.110 J/cm^2) is insufficient to significantly affect the temperature of the bulk material. Pulsed lasers or use of assisting gas enable achievement of high cooling rates. This allows the near-surface region to be processed under extreme conditions with little effect on the bulk properties. The resulting temperature profile depends on the deposited energy profile and thermal diffusion rate during laser irradiation. Reflectivity of most metals is high at low beam intensities but much lower at high intensities since this reflectivity reduces with increasing temperatures [5].
The resulting temperature profile depends on the deposited energy profile and thermal diffusion rate during laser irradiation. Only part of the laser power is useful for cutting while the rest is wasted through reflection by the workpiece surface or transmitted through successive partial reflections. Absorption of
laser radiation [6] in materials is generally expressed by Beers Lambert Law:

$$I(z) = I_o e^{-\mu z} \qquad (1)$$

where $I(z)$ is the laser intensity at depth z, I_o is the incident laser intensity and μ is the absorption coefficient of the material.

Most metal surfaces reflect IR light at 80 % and above at room temperature. The 20 % light is absorbed and converted into heat that initiates melting [7]. The nature of interaction of laser radiation with metal surface depends upon physical and metallurgical properties of the metal and all the process parameters involved. This means that to each kind of material, including its thickness and surface finishing, there will be a different collection of process parameters that will optimize a determined feature of the cutting product. Generally, metals are more difficult to machine using CO_2 laser due to their high reflectivity to this wavelength. However, this does not mean that CO_2 laser machining of metals does not exist.

Michael et al. [8] investigated productivity characteristics of a 4 kW CO_2 laser cutting system for 0.25 inch mild steel. They found that laser cutting operations generally produced regular patterns in the cut surface, known as striations whose severity (frequency and amplitude) had a direct impact on surface quality. Incomplete cuts resulted from low oxygen pressure, deterioration of the focusing lens , and/or trying to cut at a rate exceeding the power rate required for maintaining complete cutting. They controlled some parameters such as feed rate, power, assist gas pressure and laser pulse frequency while the condition of the focusing lens, nozzle gap and assist gas purity remained uncontrolled. They made the following general observations:

- An amount of variation between observations of experimental runs resulting to either the cut surface being very well within the acceptable limits established (Ra. less than 18 μ m), or very poor
- The greater the roughness values were, the wider the variations among the individual measurements became.

Uslan [9] investigated on kerf width variation during a CO_2 laser cutting of mild steel where the influence of laser power and cutting speed variations on the kerf width size was examined. It was found that the power intensity at the workpiece surface significantly influenced the kerf width size. The variation in the power intensity resulted in considerable variation in the kerf size during the cutting, which was more pronounced at lower intensities.

In order to successfully machine hard-to-wear materials, Kelly et al. [10] made innovations in laserassisted-manufacturing (LAM) which combined laser technology with traditional machining methods such as turning and milling. The laser was used as a heat source with the beam focussed on

constant workpiece speed of 0.3 m/s. It was found that the effect of assisting gas jet velocity on the surface temperature was more pronounced in the cooling cycle than in the heating cycle of the laser heating process. The workpiece movement affected the location of the maximum temperature at the surface, which moved away from the initially irradiated spot center in the direction of motion of the workpiece.

Chen [13] investigated the effects of gas composition on CO_2 laser cutting of mild steel. In his research, gas-composition variation and the gas pressure were selected as the dominant factors and their effects on the cut quality investigated, with particular reference to small variations in gas composition. He used gas mixtures composed of oxygen, argon, nitrogen and helium. From the experimental results, it was found that a high purity of oxygen was required for the high-performance CO_2 laser cutting of mild steel. Only a tiny oxygen impurity (1.25%) reduced the maximum cutting speed by 50% for 3 mm thick under low pressure up to 6 bar-inert gas cutting. Laser drilled holes have showed better profiles and geometrical accuracy than traditionally-machined holes as shown in Figure 2.

E. Observation of the microstructures

The microscope used had a resolution of 1.7, eyepiece of 8 times magnification, objective lens magnification of 40, MN11065 model and manufactured by Cooke Traton. The following procedure was used in observing the microstructure of each specimen under the microscope:

1) The specimen was focused under 544 times magnification and the microstructures observed.
2) The eyepiece of the microscope was replaced with the camera, the shutter closed, the photo taken and processed.

To be certain that the observed microstructure after the laser effect had no interference from the paint, a clean painted surface was observed under the microscope with the same magnification and its appearance
was as shown in Figure 7.

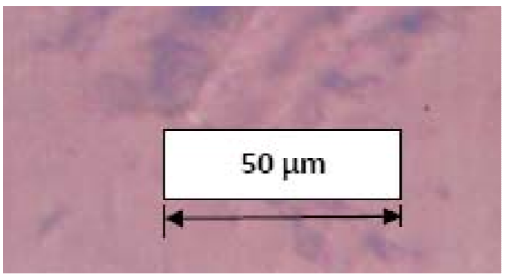

Fig. 7: Appearance of the paint surface under the microscope

III. RESULTS AND DISCUSSION

No visible marks were made on the polished and unpainted surfaces due to the high reflectance of mild steel to CO_2 laser wavelength. However, marks were visible both with the naked eye and under a microscope on the painted surfaces since the paint coating increased the absorption of the laser radiation by reducing reflection. When paper was placed along the reflection path of this beam from the mild steel surface, the paper was evaporated immediately as evidence that the beam must have been reflected rather than absorbed. Plastic placed along the same path was observed to be melting. This is due to the fact that a laser beam is reflected or absorbed depending on the surfaces of the materials.

It was observed that all the painted specimens studied had their microstructure altered on exposure while the shiny surfaces had no alteration at all. This shows that painting enhances machinability of mild steel by reducing the reflectivity of the IR energy by metallic surfaces.

Before exposure of the specimens to the laser light, the painted specimens consist of more ferrite (light polygons) and less pearlite (dark, lamellar) structures. On exposure, the diffusion of alloying elements occurs and this changes the ferrite and pearlite ratio in the structure. We can approximately estimate the amount of carbon by the amount of structures such as ferrite, pearlite and cementite. In pure iron, only ferrite exist while at 0.1% and 0.2% carbon steel, pearlite appear at the boundary of ferrite. Pearlite increases still more in place of ferrite with increasing amount of carbon content and the whole domain is occupied by pearlite in 0.8% carbon steel. Mechanical properties such as hardness and tensile strength increase while elongation and impact value decrease with increase in amount of pearlite [24].

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FROM C TO C++, C#, AND JAVA

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Abstract

Computer technology changed rapidly, programming languages also evolved with the time. The C language became a popular language and established itself as the foundation for the newer, more powerful programming languages that were developed later such as C++ (pronounce C plus plus), C# (pronounce C-sharp) and Java. The later three languages also accommodate new programming paradigm "Object-Oriented Programming (OOP),that gain widespread quickly. Now the programmers can write larger applications efficiently satisfied the demands.

Keywords:
Programming, C language, C++, Java, C#, Object-oriented

I. INTRODUCTION

Today, technology improves rapidly in both hardware and software development. Programming languages also changed over the time, allowing computer scientists, programmers to write programs, develop software applications more efficiently. C language was developed at Bell labs by Ken Thompson and Dennis Ritchie in the early 1970s. First, it was used to rewrite UNIX that resulted in a more popular, portable operation system. Gradually, C language became the most common, language of choice for writing operation systems,UNIX, Microsoft Windows, Mac OS-X, and GNU Linux were all written in C. Not only the operating systems, C language was also used to write other high level language compilers: Perl, Python, PHP,…[1]. This paper presents special features of the C language then the new enhanced features of newer languages: C++, C#, and Java. We might think, C started a new era for programming in both programming language and programming paradigm.

II. WHY C LANGUAGE?

C is flexible, offers a convenience way of writing program such as (++, --) auto-increment / decrement operators. A block of statements in C language are enclosed inside a pair of braces ({ }) instead of between two keywords "BEGIN and END".

Example:

```
i = i + 1;          //Pascal and other ancestor languages
i += 1;     //C language (Shorthand style)
or  i++;        //C language (auto-increment)
```

Example:

Look at the following program segments of "Binary Search" an array

(C language)

```
int n, key;
{
  int low = 0, high = n-1, mid;
  while(low <= high)
  {
    mid = (low + high) / 2;
    if(array[mid] > key)
      high = mid - 1;
    else if(array[mid] < key)
      low = mid + 1;
    else
      return mid;
  }
  return -1;
}
```

(Pascal)

```
var low, mid, high: index;
result: integer;
begin
low := 1;
high := n;
while(low <= high) do
begin
mid := (low + high) / 2;
if array[mid] < key then
high := mid – 1
else if array[mid] > key then
low := mid + 1;
else
result = mid;
end;
result = -1;
end;
```

[2]

Another special feature of C, it is classified as a high level language but it also has a "closed look" on the hardware, manipulation at the bit level such as the Assembly (the one and only one low level language). The operators that perform operation on bit-by-bit called "Bitwise operators", these included: & (and), | (or), ^ (xor – exclusive or) and ~ (not).

Example: In ASCII characters:

var_1 = 00100110

var_2 = 00110011

then:

var_1 & var_2 = 00100010 (both must have value of 1)

var_1 | var_2 = 00110111 (one value of 1 is enough)

var_1 ^ var_2 = 00010101 (cannot have the same value)

~var_1 = 11011001 (invert all bits of var_1)

Another interesting operation on bit is the (>>) shift-right, (<<) shift-left. We know, in binary, everything is a multiple of (2^n), hence:

if x = 00000100 (binary) or 4(decimal)

then:

x >>= 2 => x = 00000001 or just 1 (decimal – divided by 4)

x <<= 2 => x = 00010000 or 16(decimal – multiply by 4) [3]

III. FROM C TO C++

C++ is a general-purpose programming language developed by Bjarne Stroustrup, a computer scientist from Bell Labs in the 1980s. C++ is regarded as an extension of the C language and became one of the most popular programming languages in the 1990s. Most of C language included in C++ and C++ compiler can compile source program written in C. The first and most important feature that added to C language is the concept of Object-Oriented, this concept opened a new door for new programming paradigm "Object-Oriented Programming" that has been using up to today. Later, C++ added more features such as: Virtual Function and Polymorphism, Operator Overloading, Templates, and Exception Handling…[4].

III.1. VIRTUAL FUNCTIONS and POLYMORPHISM

In C++, when both super class and sub class have functions with the same names such as "print()", to display the data of the objects. These functions only display data that common by both objects of super and sub classes. This problem called "Slicing problem", the one that belongs to sub class is simply sliced off. To correct this problem, the function in super class should be declared as "virtual".

Example: Slicing problem

```
class A{          //super class
  public:
    void display(){
      cout << "From base class A.\n";
    }
};
class B: public A{  //sub class derive from A
  public:
    void display(){
      cout << "From derived class B. \n";
    }
};
int main(){        //main function that uses the two classes
  A *a;           //pointer to object A
  B b;            //object B
  a -> display();  //point to display function
  a = &b;         //assign address of b to pointer
  a -> display();  //intended to display object b
  return 0;
}
```

Output:

From base class A.

From base class A. (Only display() function in super class is invoked)

To correct this problem, we need to declare function display() in super class "virtual". Then re-run the program.

```
class A{          //super class
```

```
public:
    virtual void display(){ //virtual function
      cout << "From base class A.\n";
    }
};
```

Output:

From base class A.

From derived class B. [5]

III.2. OPERATORS OVERLOADING

Operators overloading means redefining the operation of the operators. The C++ programmers can overload most of the built-in operators in C++. Overloaded operators are functions with the keyword "operator" and followed by the symbol of the operator being redefined. After overloaded, the operators will perform the tasks according to instructions in the function operator overloading.

Example:

```
class Box{              //class Box
  private:              //private data members
    double width;     //width of the box
    double length;    //length
    double height;
  public:               //public functions
    Box(double w, double l, double h){ //value constructor
      width = w;
      length = l;
      height = h;
    }
    void setWidth(double w){ //set new width
      width = w;
    }
    void setLength(double l){ //set new length
      length = l;
    }
    void setHeight(double h){ //set new height
      height = h;
    }
    double calVolume(){        //Calculate volume
      return width * length * height;
    }
    //Overload "+" operator to add two Box objects
    Box operator+(const Box& b){
      Box box;                //instance Box object b
      box.width = this->width + b.width;
      box.length = this->length + b.length;
```

```
        box.height = this->height + b.height;
        return box;
      }
};
int main(){          //main function to use class Box
  Box b1 = new Box(6.0, 7.0, 5.0);   //Box b1
  Box b2 = new Box(12.0, 13.0, 10.0) //Box b2
  Box b3 = new Box(0, 0, 0);
  cout << "Volume Box b1: " << b1.calVolume() << endl;
  cout << "Volume Box b2: " << b2.calVolume() << endl;
  //Add two Box objects
b3 = b1 + b2;
  cout << "Volume Box b3: " << b3.calVolume() << endl;
  return 0;
}
```

Output:

Volume Box b1: 210

Volume Box b2: 1560

Volume Box b3: 5400 (not eaqual 210 + 1560) [6]

IV. FROM C, C++ TO C#

In year 2000, .NET (dot NET) revolutionized the way for programmers to build Web and Windows applications. C# (pronounce C-Sharp) was developed by Microsoft's R&D team, led by Anders Hejlsberg and Scott Wiltamuth, it was the language of choice for .NET platform,built from lessons learned from other older languages: C, C++, and Java. C# offers many new features:

- C# brings back support for "struct" (structure) concept that was missing in Java. A struct is a restricted, lightweight type that can't inherit or be inherited from a class but a struct can implement an interface.

Example:

```
        public struct location{          //defind struct location
      public int x{get; set;}
      public int y{get; set;}
      public override string ToString(){
        return (String.Format("{0}, {1}, x, y));
      }
    }[7]
```

- C# provides support for "delegate", an indirect technique for methods invocations.A delegate can be explained as a pointer to a method in C++

Example:

1. Without using delegate

```
class Controller{              //Without using delegate
  private FoldingMachine folder;   //Different machines
```

```
  private WeldingMachine welder;
  private PaintingMachine painter;
  ...
  public void ShutDown(){          //Shutdown machines
    folder.StopFolding();
    welder.FinishWelding();
    painter.PaintOff();
  }
  ...
}
```

2. Using delegate

```
class Controller{                  //Using delegate
  delegate void stopMachineryDelegate();
  private stopMachineryDelegate stopMachine;
  ...
  public Controller(){
    this.stopMachine += folder.StopFolding;
    this.stopMachine += welder.FinishWelding;
    this.stopMachine += painter.PainOff;
  }
  ...
}
```

- C# also provides support for "Lambda Expression", a new feature which is an expression that returns a function (method). Lambda Expression using syntax and semantics of the Lambda Calculus such as in the following examples.

Examples:

```
x => x * x                //Symbol "=>" is Lambda Expression in C#
x => {return x * x;}      //Same as above
(int x) => x / 2
() => folder.StopFolding() //Calling a method
(x, y) => {x++; return x / y}
```

- Other new features of C# included:

1. LINQ (Language Integrated Query) that similar to SQL (Structured Query Language) used to access database.

```
        IEnumerable<string> customerFirstNames =
      customer.Select(cust => cust.FirstName);
    foreach (String name incustomerFirstNames){
      Console.WriteLine(name;
    }
```

From the example above, we can see the “Select” verb of SQL and also a new version of “for loop” in C#, foreach (…)

2. ADO.NET that can be used to fetch and display data from a Microsoft SQL server database

```
try{        //Fetch data and display order
...
while(dataReader.Read()){
  //Code to display the current row
 }
}
```

3. ASP.NET (Active Server Page) for development of Web applications. ASP.NET supports HTML documents.

```
<asp:TextBox BackColor=”Blue” ForeColor=”White” Runat=”Server” />
<asp:Label BackColor=”White” ForeColor=”Blue” Runat=”Server Font-
Bold=”True” />[8]
```

V. JAVA

Two important factors that influenced computer language are: improvements in the art of programming and the computing environment. Java is no exception, must satisfied the two factors before becoming the most popular, widespread programming languages. It was developed at Sun Microsystems in 1991, by a team led by James Gosling. The new language was initially named “Oak” then renamed “Java” in 1995.

Unlike the other older languages, that was designed to run on a particular machine (CPU), Java is portable language that can run on multi-platforms (cross-platforms), the Internet and World Wide Web (WWW).

V.1. JAVA and C, C++

Java statements are very much the same as C, C++ statements, we can say Java inherits its syntax from C and concept of object-oriented from C++. An example of adopting C’s syntax can be found in input/output statements: “scanf” and “printf”. In the early years of Java, to input data from the keyboard, we need to download class keyboard from the Internet, later we have class “Scanner” for reading an input stream. The same for output, we used class “DecimalFormat” to format numeric values, now it is convinience and efficiently to use the printf statement.

Example:

```
Scanner input = new Scanner(system.in);//instance of class Scanner
int intNumber = input.nextInt();      //Read integer value
System.out.printf(“%4d”, intNumber);  //use 4 spaces to print
```

An important note that even influenced by C, C++, Java is not an extension or enhanced version of C++. It was designed for some special purposes not for replacing C++.

V.2. JAVA and C#

Microsoft developed C# as the leading language on **.**NET platform a few years after the release of Java. Both Java and C# inherit syntax and features from C, C++, but C# is closer to the "C family" and could be regarded as an extension of C and C++. In some aspect, C# refines Java statements make them more convenience to code. One of the requirement to create a Javabean is each data member of the class must has a pair of "get and set" methods, C# refines by combining them together into one.

Example:

Java:
```
public class Number{      //Java class Number
  private double number; //Data member
  ...
  public double getNumber{ //Get the number
    return number;
  }
  public void setNumber(double n){ //Set new value
    number = n;
  }
  ...
} //End Java class Number
```

C#:
```
public class Number{       //C# class Number
  private double number;  //Data member
  ...
  public double Num{      //Get and Set method for number
    get{                  //Get number
      return number;
    }
    set{                  //Set new value
      number = value;
    }
  }
  ...
}[10]
```

VI. CONCLUSION

We are living in a changing world and it changes rapidly in science and technology. Computer programming is a very important skill for computer scientists and programmers as the demand for more new applications increase. We might think, programming is an art of problem solving using computer, however, without a suitable programming language, the programmer's jobs would be more difficult, just like an artist without a right tool.

From this paper, we can see the evolution of programming languages over the time, the new language would inherit characteristics of the ancestors then adding new or enhanced features.

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CO_2 laser machining of wood, perspex and glass with and without use of assist gas

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***Abstract*—*In this paper, we investigate the effect of CO_2 laser machining on wood, perspex and glass. These materials are very important due to their wide applications and thus there is need to machine them as desired. Glass is a hard, optically transparent and used for a variety of purposes such as eyewear, bottles, windows and even certain types of furniture. Perspex is the clear, light weighted, hard and thick plastic, widely used for watch glasses, advertising signs, domestic baths, motorboat windscreens, aircraft canopies, and protective shields. To eliminate the possibility of the CO_2 light being diffused by dirt/dust particles on the surface of these materials being experimented on, thorough cleaning of the surfaces is done and these specimens left to dry before use. A continuous wave (cw) CO_2 laser beam with an estimated power of 35 Watts is then focused on the surfaces of the specimens. Machining time and the number of scans are varied and their effect on depth, hole diameters, kerf widths, taper, aspect ratio and heat-affected-zone (HAZ) investigated. Effect of compressed air as the assist gas on hole profiles and the point at which glass cracks was also investigated. During these experiments, the machining velocity, laser and optics parameters were kept constant. Results showed that in an increase in the input parameters resulted in an increase in the features under investigation.*

Keywords—CO_2 laser, continuous wave, laser ablation, quality machining, machining time.

I. Introduction

PLYWOOD is one of the most widely used wood structural products due to its flexibility, low cost, workability, re-usability, resistance to cracking, shrinkage, splitting and twisting/warping, and its general high degree of strength, and can be locally manufactured. It is used in many applications that need high-quality, high-strength sheet material. Lasers offer a number of attractive advantages for the cutting of timber, plywood, and particleboard. In particular, it provides narrow kerfs of 0.3-0.8 mm, the absence of sawdust and minimum or no noise. While the use of a laser eliminates rough, torn-out and fuzzy edges which are common with conventional sawing techniques, it is characterized by burned edges produced by the laser heat. Greater amounts of charring will result when the material thickness is increased, thereby necessitating the use of small cutting feed-rates. CO_2 laser has been commonly used to machine most non-metallic materials like wood because these materials highly absorb the CO_2 laser wavelength of 10.6 μm. Conventional glass cutting is done by scoring and breaking which produces microcracks and splinters, and leaves cutting oil residues.

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These microcracks and oil residual lead to lowered strength and pollution of the glass sheets respectively. If the glass has to be bent or tempered, further grinding, polishing and washing processes become necessary. Most types of glass are prone to thermal shock and are therefore laser is generally not suitable for cutting. The instantaneous heat of the laser beam provides cutting action by both vaporization and the blowing away of molten glass from the cut zone [1].

There are many parameters which influence laser machining and therefore have to be considered for quality machining to be achieved. These input parameters include [2]:

- Laser parameters such as laser power, wavelength, depth of focus (DOF), focal length, beam diameter
- Material parameters such as thermal diffusivity, thermal conductivity, reflectivity, absorptivity, material thickness, initial temperature and humidity
- Machining parameters such as scanning speed, positioning of the focal point, incidence angle, type and pressure of the assist gas.

Nukman et al. [3] investigated the effects of CO_2 laser cutting parameters on the cut quality of several selected Malaysian wood. The processing variables taken into investigation were laser power, nozzle stand-of distance (SOD) or focal point position, nozzle size, assist gas pressure, types of assist gas and cutting speed. These were their observations:

- Cutting parameters selected for laser cutting of wood were the materials moisture and air content, workpiece thickness and density.
- For material thickness of 10 mm for all wood samples, it was not possible to achieve a successful cut using laser power of 100 W at 1.2 m/min cutting speed.
- Due to exothermic reaction, cutting with compressed air exhibited severe burns and charring with larger kerf widths, over cuts and higher portions of material loss.
- Use of nitrogen was reliable in reducing material loss and over burning due to the compensation of heat accumulation by offering cooler and inert environment to the cutting process.
- Closer dimensional accuracy and acceptable surface finish in laser cutting of wood were obtained when nitrogen was used in assisting the cutting process as compared to the use of compressed air.

Szymani et al. [4] investigated on modern cutting techniques in wood machining processes by evaluating three new approaches to kerfless wood cutting. These are the use of

cutters, high-velocity liquid jet and laser beam. It was apparent that the high-velocity liquid jet and laser beam offer great potential in secondary manufacture, in particular for cutting of intricate contours and complex computer-controlled operations.

Migliore et al. [5] observed that with an assist gas, factors to be considered include the type, flow rate and purity. These influence the speed of machining and surface finish. For instance, when oxygen is used as an assisting gas, the exothermic reaction results in reduction of machining time.

Begic et al. [6] noted that some gaseous impurities can modify the characteristics of the beam generated by a CO_2 laser and cause some nonreproducible performances such as loss of power, reduced stability of the laser beam and shorter service life for electrodes and delivery mirrors.

Yilbas [7] assessed cutting quality and thermal efficiency of a laser gas assisted cut- ting process. He found that increasing laser beam scanning speed reduced the kerf width and that the kerf width increased with increasing laser output power. The main effects of all the parameters employed had significant influence on the resulting cutting quality.

In alloys, assist gases are used in industrial laser machining to protect the laser optics by blow back of ejected debris and to allow a chemical reaction between the substrate and assist gas in order to generate more energy as noted by Voisey et al. [8]. These authors investigated the effects of using assist gases in the drilling of different substrates with the aim of investigating whether assist gases are beneficial to the laser drilling of superalloys. No noticeable variation in the mass of substrate removed per hole was observed for either assist gas used to drill both the blind and through holes. Changing from an oxidising (oxygen) to an inert assist gas (nitrogen) did not have any discernable effect, indicating that the superalloy, as well as the zirconia top coat, do not have any chemical interaction with the oxygen assist gas. The lack of reaction between zirconia and oxygen was expected since zirconia was already an oxide. There exists a wide range of materials that has been laser machined including several types of rocks [9].

Berrie et al. [10] experimented on the effect of lens, position and focal plane, speed of cut and power on the cutting and drilling rates of perspex. They found that the drilling rate was faster for longer focal lengths in the time range investigated and an increase in power increased the rate of drilling. Another point noted was that holes drilled with different lenses differed only superficially with the short focal lengths producing shorter, wider holes, whereas with the longer focal lengths, tapering was more pronounced. At low speeds or large depths there was little or no dependency of depth of cut on the focal length of the lens.

II. Experimental Set-up

The laser generation tube was set up as shown in Figure 1. After the laser beam generation, the beam was manipulated through the beam delivery system as shown in Figure 2. The arrows indicate the beam manipulation. When machining each material, the scanning speed, laser and focusing optics were held constant to investigating properties such as the kerf width while machining time and the number of scans were varied and their effects on cut parameters investigated.

Fig. 1. Laser generation tube

Fig. 2. Laser beam delivery system

During the experiments, the aim was to focus the beam on the workpiece so as to concentrate the beam to the minimum spot possible and thus achieve maximum power density which would consequently increase the material removal rate (MRR) and reduce the HAZ. The workpiece was placed with the surface on the focal plane. With the focal length of the lens as 38 mm, Equation 1 was used where H and h are in mm.

$$H = h + 38 \quad (1)$$

For glass, each specimen was placed under the focused beam and the time it took to crack measured. The hole diameter, crack length and thickness were measured using the profile projector.

To investigate the effect of an assist gas in glass cutting, one set of experiments was done without any assist gas while the other was done with compressed air as the assist gas. The interaction time between the beam and the workpiece was varied from 5-25 seconds and the effect on hole diameter measured. Three different experiments were performed on the specimens as follows:

1) experiments without any assist gas
2) experiments with assist gas at 10 mm above the workpiece surface, at 45 degrees inclination
3) experiments with assist gas at 3 mm above the workpiece surface, at 45 degrees.

III. RESULTS AND DISCUSSION

A. Wood drilling with CO_2 laser

For the holes or slots made using the CO_2 laser, HAZ was evident and defined as a darkened area around the holes or slots where the beam intensity was not sufficient for a clean cut. The holes were also tapered as illustrated in Figure 3. This was due to the Gaussian power distribution of the beam. An increase in machining time resulted in an increase in kerf widths, hole diameters and depth. The increase in these dimensions with an increase in machining time or number of passes is due to the fact that more laser energy is absorbed by the material as time progresses resulting in more material being ablated. However, due to the limited laser beam diameter and DOF, these measured dimensions seem to reach some saturation for this stationary beam and thus do not increase infinitely with an increase in machining time or number of passes.

Figure 4 shows that an increase in machining time results in an increase in hole diameter, depth and HAZ. when drilling wood. This is an increase in machining time means an increase in the interaction time between the material and the laser beam. This means more energy is absorbed by the workpiece and thus removes more materials. In Figure 5, the charred region refers to the darkened area along the cutting path. This increases with an increase in machining time due to the heat wasted around the machining path. Figure 6 shows that the depth machinable can be predicted using a simple equation. This is important so that one does not machine for so long as this does not increase the depth past some saturation. This would only increase manufacturing cost and HAZ.

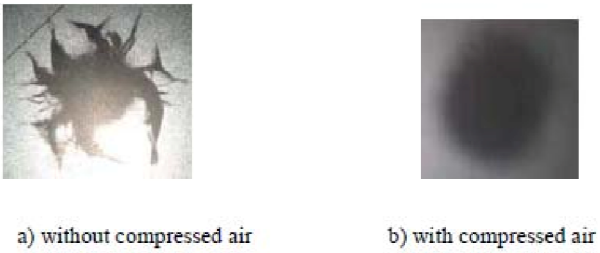

Fig. 15. Effect of compressed air on hole profile

IV. CONCLUSION

From this study, the following conclusions can be drawn:

- There is a threshold exposure time (1 second) below which no material can be ablated from either wood or perspex.
- From the depth prediction graphs, one can concentrate on optimum machining time or number of passes and thus reduce on manufacturing costs. (IR) energy from CO_2 laser.
- Assist gas improves geometrical accuracy.
- Use of assist gas reduces the chances of glass cracking.

ACKNOWLEDGMENT

This work is supported by Jomo Kenyatta University of Agriculture and Technology.

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AN EVALUATION OF ENTERPRISE RESOURCE PLANNING SYSTEMS IMPLEMENTATION EXPERIENCES FOR SELECTED PUBLIC UNIVERSITIES IN KENYA

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ABSTRACT

Implementation of Enterprise Resource Planning (ERP) Systems has found widespread usage in large and mid-sized institutions worldwide. There has been a rapid increase in implementation of these systems in management and administration of institutions of higher learning. To establish the implementation experience in public universities in Kenya, the research study has used the Diffusion of Innovations Theory and the Information Systems Success Model. The study was carried out on evaluation of implemented integrated enterprise resource planning systems in selected public universities in Kenya. The study sought to investigate existing implementation of enterprise resource planning systems in public university management in Kenya and how they have influenced automation efforts in these institutions. Various challenges are evaluated on the ease of use of integrated systems in administration and management of public universities. Recommendations are drawn on probable ways of utilizing the enterprise systems not only to overcome existing management challenges but also improve service delivery in line with respective institutional strategic objectives. From the findings of the study, most of the implementation projects had been abandoned or stalled altogether. Challenges associated with institutional connectivity and limited skilled expertise to drive the implementation processes were highlighted as leading influencers of implementation processes in respective public universities. The study recommends increased investments towards improvement in institutional connectivity, blending of internal and external skilled expertise to drive implementation initiatives and regular contribution of implementation experiences in internal and external seminars for future studies and contribution to the body of knowledge.

Keywords: ERP Systems, Integrated Information Systems, Implementation Processes, Strategic Objectives, Management Challenges, Skilled Expertise

Background of Study

According to Gupta (2008) ERP systems have gained widespread appeal in the 21st century owing to their "do it all" approach to organizational management. With more users seeking to link application systems to departmental processes, public universities in Kenya are seeking ways to integrate their operations in a bid to cut on operational costs, offer timely response to their clients and interact with their stakeholders in 'real-time'. To meet these requirements, public universities in Kenya have resorted to use of ERP systems to automate their operations on a standardized platform in line with their strategic plans. With past studies laying emphasis on ERP systems in business scenarios in Kenya, the study herein sought to explore implementation of ERP systems in Kenyan public universities in their quest to improve quality of their service to meet regional as well as global standards.

Statement of the Problem

The Implementation experiences as reviewed by Huang and Palvia (2001) vary across different developing countries. In the Kenyan context, much of the literature on ERP systems has centred on manufacturing and business sectors. With a glaring lack of clarity on implementation experiences especially in public universities as they seek to implement ERP systems there was need for a study to unearth implementation experiences for public universities in Kenya. It is on this basis that the study sought to evaluate implementation experiences based on quality of systems used, communication and service delivery functions to public universities in Kenya.

Objectives of the study

The study utilized one main objective with three specific objectives to evaluate implementation experiences in public universities in their use of Enterprise Resource Planning Systems. The main objective of the study was to find out the implementation experiences in public universities in their use of Enterprise Resource Planning Systems

Specific Objectives

The study focussed on the following specific objectives:

(i) To examine how ERP systems used affect implementation experiences for public universities
(ii) To establish how ERP based communication affects implementation experiences for various public universities in Kenya
(iii) To determine how ERP systems in service delivery influence implementation experiences in public universities in Kenya

Research Questions

The research study sought to answer the following questions

(i) How does ERP systems used affect the implementation experiences for public university in Kenya?
(ii) How does ERP systems based communication processes affect implementation experiences for public universities in Kenya?
(iii) How does use of ERP systems affect service delivery in public universities in Kenya?

Scope of the Study

The research study sought to establish the experiences of various public universities in Kenya in their implementation of Enterprise Resource Planning Systems to automate their operations. This included type of system implementation cycles used, benefits realized from the systems and challenges experienced as a result of use of ERP systems in their management processes. In carrying out the study, the target population comprised of 15 (fifteen) ICT administrators and technicians in each of the three public universities in Kenya under study. The choice of ICT administrators and technicians in public universities as target respondents owed to their knowledgeable background on the research problem. This helped to obtain relevant data for use in the research study.

LITERATURE REVIEW

As part of the theoretical framework, the study has been anchored on the Diffusion of Innovations Theory (DOI/DIT) by Rogers, (2003).The theory has been used to provide a theoretical backbone to the study. In addition to the Diffusion of Innovations Theory, the study further utilizes the Information Systems Success (ISS) model to further review the key variables in the research study.

Diffusion of Innovations Theory

Diffusion of Innovations (DOI) Theory was coined by E.M Rogers in 1962 and later revised in 2003. It is a widely used theory in social science disciplines. The theory has its basis in communications and seeks to explain how an idea or product gains momentum and spreads through a specific population or social system. The result of this diffusion is that users take up the new idea or innovation. Adoption as brought out in the theory assumes that users react differently to an innovation compared to previous products or innovations. This facilitates the diffusion process.

Diffusion of Innovations Theory posits that theoretically, 49%-87% of the variance of an innovator's rate of adoption is explained by its perceived attributes, type of innovation decision, and nature of social system which the innovation is diffusing and the extent of the agents' promotion efforts in diffusing the innovation (Nzuki, 2012). The theory is useful to both the developers and users of ERP systems in evaluating how these systems are implemented in various projects. As argued by Rogers (1995), an innovation such as use of Enterprise systems in management of higher education institutions is regarded as a technological innovation. This is realized as a result of paradigm shift from stand-alone information systems to integrated information systems.

As argued by Sahin (2006), the process of implementing new innovations as discussed at length by Rogers (2003) in the book, *Diffusion of Innovations,* the studies cited in the publication border on various disciplines including education and technology. The theory advanced by Rogers (2003) has found widespread usage in understanding technology diffusion and adoption. As cited by Medlin (2001), the theory is useful in investigating implementation of technology in higher education environments. In carrying out the research study, the theory is useful in evaluating the experiences of public universities in Kenya in their implementation of enterprise resource planning systems.

The research study borrows heavily from the third (decision) and fourth (implementation) steps in the DOI theory. With deployment of ERP systems in management of public universities in kenya interpreted as an innovative strategy in the study, various institutions are assumed to have undergone the first, second, and third processes in the diffusion of innovations theory as advanced by Rogers (2003). These include gathering knowledge about the ERP systems, persuading stakeholders to support the selected systems in automating their institutional operations and making the decision to implement the systems.

While guided by the diffusion of innovations theory, the researcher will sought to establish the institutional experiences during the implementation phase of the ERP systems in public universities.

Information Systems Success Model

The research study employed use of the Information Systems Success model. The information systems success model as advanced by Delone & McLean (2003) is based on earlier research in communications by Shannon and Weaver as well Mason's theory on Information Influence. As highlighted in the model, three key pillars of information systems success are advanced. These include System Quality, Information Quality and Service Quality. The theoretical model makes use of a causal relationship to analyse success of implementation of information systems in institutions.

Information Systems Success Model as revised by DeLone and McLean comprises of six interrelated dimensions which influence success in implementation of an information system. These include information quality system quality and service quality as independent aspects. These affect the intention to use, user satisfaction and net benefits derived from implementation of an information system. According to the model, an information system such as an ERP system can be evaluated in terms of information, system and service quality. These subsequently determine system use, intended use, target user satisfaction and net benefits from deployment of the system. Net benefits derived from use of an ERP system can be of either positive or negative influence to satisfaction of users. Net benefits from implementation of an ERP system help to determine feasibility of implemented system (DeLone & McLean, 2003).

The information systems success model was useful in studying integrated institutional management information systems and their usage in public universities in Kenya. By using the model, the objectives of the research study were best addressed to ascertain not only challenges but also benefits of deployment of these systems in management of public universities.

EMPIRICAL REVIEW

ERP systems have found widespread usage in large organizations across various continents. To keep up with the management demands in the 21st century as observed by Nyandiere *et al* (2012), universities have turned to ERPs to replace their legacy systems. Though initial implementation was observed in manufacturing industries, universities have taken up the systems to provide institutional-wide automation for their processes (Ferrell, 2003). This has aided them automate their core business areas in student administration, finance, staffing, client management among others. On implementation, these systems are anticipated to provide increased efficiency and effectiveness of processes, reduce overhead costs in ICT, improve decision making, improve resource management as well as building business innovation while supporting strategic change (Sullivan and Bozeman, 2010).

As argued by Davenport (2003), ERP systems provide seamless integration of all information flowing through a company's departments. With the seamless integration of information within institutions, managers are able to overcome frustrations emanating from incompatible systems and inconsistent operating practices. Acquisition of these systems may be through commercial off-the-shelf systems or custom designed systems in line with a university's needs. Past studies in implementation of ERP systems in educational institutions have focussed more on the benefits that an institution can derive from adopting an ERP system. However, more literature on pitfalls facing these implementation experiences needs to be highlighted to inform current and future adoption of ERP systems in university administration (Yetton and Sharma, 2003)

According to Verville and Halingten (2003), ERP systems are used to connect back-office operations such as manufacturing, financial and human resources into one system. In the current decade, enterprise resource planning has evolved to a suite of application modules that are used to link back-office operations to front-office operation as well as internal and external supply chains. They conjoin functional areas and business processes in a seamless integrated environment. This provides a wider scope for applicability to organizations. Enterprise Resource Planning systems have gained widespread usage in large corporations and institutions across the globe. In contemporary trends witnessed in higher education as pointed out by Zornada (2005), universities have turned to ERP systems as a means of replacing existing management and administration techniques by use of computer systems.

Pollock (2004) in a study aimed on ERP systems use in a UK university points out that the uniqueness of a university set up makes most business ERP systems incompatible with their functions. This necessitates a custom development of a system compatible with the structure and functions of a specific university. The choice of either a custom development or adoption of a readily available system should be informed by informed by a thorough systems analysis and design evaluation while putting the institutional strategic objectives into consideration (Basoglu and Kerimoglu, 2007). This can be achieved by drawing up an elaborate implementation framework to guide the process.

Implementation of ERP systems in institutions is a complex process. A multiplicity of factors influences success rates in implementation of ERP systems from one organization to another. With the current seeking to establish the effect of some of these factors in implementation of ERP systems in public universities in Kenya, earlier studies in developed societies such as Shah *et al.* (2011) cite factors such as top management support, user involvement, vendor support, overlooking of change management aspects, turnover of vendors team member, transfer of top management in beneficiary institutions as key factors affecting successful implementation of ERP systems in organizations. Other factors identified include project cost overruns and delayed project schedules and their effect on user requirements.

Implementation of ERP systems requires drastic change to the existing work processes and such change needs to be managed for its success. Past studies have indicated that successful implementation of ERP systems in institutions is concerned with the degree of mutual fit between an ERP system selected and business processes in an institution (Olson, 2004). Other studies such as Nah *et al.* (2001) identify various challenges that organizations face during ERP implementation. These if reviewed by universities provide useful resources to inform their implementation processes and avoid potential pitfalls. These challenges involve people, processes and technology used in the implementation processes.

Implementation of ERP systems in public universities is not a technology but a people project as argued by Leon (2008). In this regard, preference is given to the role of users in determining the implementation of an enterprise system. Zhang *et al.* (2002) further argues that user involvement at initial stages of ERP system implementation is helpful in understanding a system so as to provide valuable feedback. Hartwich and Barki (2001) explain user involvement as a psychological state of the individual and as the importance and personal relevance of an ERP system deployment to a user. In light of this, user participation in defining needs and implementation of ERP systems in public universities is essential especially in improving service delivery. Matching user needs to choice of system used, service requirements and functional abilities of the chosen system are essential in determining the success in implementation of an ERP system (Motwani *et al*, 2005).

Acquisition of established custom computer systems for institutional information convergence is a popular trend in universities across the global divide. As argued by Pollock, (2004), more and more universities are adapting general solutions to their integrated management information system needs. To

this end, use of generic software systems to meet the widest possible scope of their activities and processes is implemented. This is aimed at providing a host of management solutions which include cost savings, expediting processes and improving access through reliable platforms. However, attainment of these objectives is likely to vary from one institution to another and formed part of the research study in the Kenyan context.

Literature Summary

ERP systems have found widespread usage in large and mid-sized corporations worldwide. In the last decade as argued by Cornford & Pollock (2004), there has been a rapid increase in implementation of ERP systems in management and administration of educational institutions. In this regard, universities have turned to ERP systems to replace existing management and administration computer systems. In analysing rollout of ERP systems in Public Universities, focus has been placed on development, implementation and use of both generic and university specific functionalities. These technologies have been used to improve service delivery in public universities as they claim their footing in the higher education landscape.

With the promise of improved efficiency, reduction of duplication of resources and improvement in process timelines, public universities in Kenya have turned to implementation of ERP systems. These are seen to provide potential solutions to address growing automation requirements for efficiency. Feasibility of these systems against the backdrop of their promise in revolutionizing the higher education landscape in Kenya has been revisited in the research study herein. To achieve this end, the study has utilized the 'Diffusion of Innovations Theory' by Rogers (2003) and the 'Information Systems Success Model' advanced by Delone & McLean (2003) to provide a detailed examination of implementation of ERP systems in Kenyan public universities. The theoretical basis and empirical review brought out in the study also influenced the formulation of the illustrated conceptual framework which guided the entire research study.

RESEARCH METHODOLOGY

The research study adopted a descriptive research design. The choice for use of descriptive research design was to provide a comparative approach to the use of enterprise resource planning systems in integrating management of public universities in Kenya against a backdrop of other success cases in developing and developed nations. This also helped the researcher in using comparative statistical methods to analyse the research subject in the target public universities.

Target Population

The target population comprised of ICT personnel in public universities in Kenya. A sample population was derived from their respective ICT departments. The choice of ICT departments in these institutions owes to their familiarity with the subject of the proposed study.

Sampling and Sampling Design

Purposive sampling was employed in arriving at sample populations that were used in the research study. According to Mugenda & Mugenda (2003), purposive sampling allows a researcher to use cases that have the required information with respect to the objectives of the study. Case subjects can thus be hand-picked since they are informative or have the desired characteristics. The choice of purposive sampling in the proposed study is to ensure that key aspects of the study population such as skill levels and experience in use of ERP systems are taken into consideration. Out of a total population of 45 (Forty

five) ICT technicians and administrators in the three public universities that were studied based on an informal survey by the researcher, a census was carried out to maximize responses to the study.

Data Collection

From the research study, this comprised of gathering responses from the target population for further analysis. Data collection comprised of data sources, research instruments and data collection procedures. The research study relied on both primary and secondary data sources. Primary data was gathered using structured questionnaires. In addition to the primary data, secondary data from journals, white-papers and e-books was also used to provide comparative perspectives to the study. The research study utilized questionnaires as the primary research tools.

Validity and Reliability

According to Mugenda and Mugenda (2003) validity is the accuracy and meaningfulness of inferences based on research results. It comprises of the degree to which results obtained from the data analysis represent the subject of the study. To ensure validity, accuracy of research data has been put into consideration to represent variables of the study. To realize this, all the independent and depend variables were included in the study questionnaire.

Reliability of research as argued by Mugenda and Mugenda (2003) refers to the degree to which a research instrument yields consistent results or data after repeated trials. Reliability in research can be influenced by random error. This may arise from inaccurate coding, ambiguity of instructions to respondents, fatigue on researcher and respondents and bias. To address reliability of the research, pre-testing of the research instruments through a pilot test was done. The test-retest method used as observed by Ngechu (2004) helped in obtaining a coefficient of reliability and suitability of the instrument. If the coefficient is low, a review of the instrument would have been done. If the coefficient was high, which happened to be the case, the study instrument used was deemed to have high test-retest reliability in carrying out the study.

Data Analysis & Presentation

Data collected from the research study was analysed using descriptive statistics, relational statistics, factor analysis and logit regression analysis. This helped in providing a relational summary of findings on the subject across all target populations (Gujarati, 2003). With considerable inferential data obtained from the research study, use of a logit regression model was utilized to analyse the relationships between the independent variables and the dependent variable. The model used was as follows: $P_i=E(Y=1|X_i) = \beta_0+\beta_1X_1+ \beta_2X_2 +\beta_3X_3+ \varepsilon$

Ethical Considerations

Ethical practices that were put into consideration during the research study included confidentiality of responses, anonymity of respondents, honesty in reporting findings from the proposed study and integrity in handling data and information collected from the research study. In addition, the researcher used random identities to ensure privacy of participating institutions. Presentation of findings has been done without disclosure of respondents' identities.

DATA ANALYSIS

The objective of the study was to evaluate the experiences of public universities in their implementation of ERP systems. In evaluating these experiences, the study sought to establish the experiences based on

quality, communication and service delivery aided by use of ERP systems and how they affect the implementation experiences of the selected universities. The study was carried out in three public universities as part of twenty three (23) public universities which were fully accredited by the commission for university education by the end of year 2013.

Response Rate and Reliability of Data

A total of 93 structured questionnaires were distributed in all the three selected universities. These targeted 31 members of ICT directorates in each of the three selected universities. The study collected data from 79 respondents which constituted of a response rate of 84.9%. This was adequate for statistical analysis of findings. As argued by Mugenda and Mugenda (2003), a response rate above 70% is excellent. In this regard, a response rate of 84.9% was adequate for the purpose of this study.

Response Rate	Frequency	Percentage
Response	79	84.9
Non-Response	14	15.1
TOTAL	**93**	**100**

Source: Research Data, 2014

Reliability of Study Findings

Cronbach's Alpha

Variable	Cronbach's Alpha	No. of Items
ERP System Attributes	.834	7
Communication	.793	8
Service Delivery	.802	6

Source: Research Data, 2014

In evaluating reliability of findings through the study instrument used, a pilot study was carried out on 10 respondents. Using Cronbach's Alpha, internal consistency was evaluated. This was aimed at establishing how sets of variables are related in the group. As argued by Nunnally (1994), a construct composite reliability coefficient above 0.7 is considered adequate for reliability of a research tool in carrying out a study.

From the results of the pilot study, 'system attributes' scale had a composite reliability coefficient of 0.834. 'Communication' scale had a composite reliability coefficient of 0.793. 'Service Delivery' had a composite reliability coefficient of 0.802. From the pilot study, the scales measuring the objectives had a very high reliability. This was indicative that the research tool was sufficiently reliable to carry out the study without further amendment.

Inferential Statistics

In analysing inferential data collected from the study, regression analysis was conducted to determine whether ERP system attributes, communication and ERP based service delivery influence implementation of ERP systems in public universities. The following model was used in analysing inferential data:

$$P_i=E(Y=1|X_i) = \beta_0+\beta_1X_1+ \beta_2X_2 +\beta_3X_3+ \varepsilon$$

Where Y=1 implies that a public university has implemented an ERP system; X_1 refers to the quality of ERP system implemented at the public university. X_2 refers to the communication function of the ERP system implemented in the institution and X_3 refers to the service delivery component of the ERP system implemented in the institution. These are the independent variables in the study. β_0 is a constant while ε is the error term in the function. The error term ε was computed when checking for reliability of research questionnaires prior to the actual study. $E(Y=1|X_i)$ implies a function with a regressand Y and regressor X_i.

Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.869	.755	.720	.96574

From the model summary in table 4.9 above, there was a very strong positive relationship (R=0.869) between the dependent variable (ERP implementation experience) and the independent variables (system quality, communication and service delivery). The value of adjusted R Square (R^2= 0.720) indicates that 72.0% of ERP implementation experiences in public universities in Kenya could be explained by the independent variables of the study which comprise of ERP system quality, ERP based communication and Service delivery over ERP platforms.

Estimated parameters of variables affecting ERP implementation experiences

Variable	Regression Coefficient (β)	Wald Statistics	t-value	p-value
1. System attributes	0.004	5.552	2.000	0.018
2. ERP based Communication	1.643	1.643	1.269	0.201
3. ERP based service delivery	4.846	1.379	2.211	0.013
Constant	-32.246	4.185	-2.123	0.032
Chi-square (df = 3)	= 54.2			
(-2) Log likelihood	= 13.642			
Accuracy of prediction overall (%)	= 97.90			
Nagelkerke R^2	= 0.755			

By discriminating predictors on basis of magnitude of Eigen values, the logit model used was run several times until three (3) predictors which had Eigen values higher than 1.532 selected as per table 4.9.2. The predictors were ERP system attributes, ERP based communication, and ERP based service delivery. Regression coefficients reflected standard errors, t-values, Wald statistics and p-values. The logit model generated a chi-square value of 54.2 and p-value 0.000 which was significant since the P-value was less than 0.05. Further to this, the logit model's overall prediction accuracy was 97.9% indicating that the overall fit of the model was good.

The logit model above established that taking all variables at a constant, a unit increase in ERP system attributes results in to a 0.004 increase in ERP implementation experience in public universities. A unit increase in ERP based communication yields 1.643 increase in ERP implementation experience. In addition, a unit increase in ERP based service delivery leads to a 4.846 increase in ERP implementation experience in public universities. From the model above, it is worth noting that ERP based service delivery contributes most to ERP implementation experiences in public universities in Kenya. At 5% level of significance; ERP system attributes had a 0.018 level of significance, ERP based communication had 0.201 level of significance and ERP based service delivery had a 0.013 level of significance. This indicates that ERP based service delivery is the most significant factor affecting ERP implementation experiences in public universities in Kenya.

In addition, the logit model used yielded a Nagelkerke R^2 value of 0.755 meaning that 75.5% of the dependent variable (ERP implementation experience) can be explained by the independent variables; system attributes, ERP based communication and ERP based service delivery. The logit model generated a -2log likelihood value of 13.642, which indicates that the model was appropriate.

RESEARCH FINDINGS

ERP System Attributes

The study established that ERP system attributes have significant influence on implementation experiences of enterprise systems in public universities. Quality and functional attributes of implemented ERP systems have a significant influence on implementation experiences of Kenyan universities. With respect to integration with existing systems prior to ERP implementation, choice of systems by public universities had average effect reflecting significant contribution towards shaping their implementation experiences.

ERP Based Service Delivery

Integration of ERP systems with business software used by public universities, migration of data to ERP platforms and data security over ERP platforms had average effect on implementation experiences for public universities in their quest to automate their operations over an ERP platform. As brought out in the study findings, successful implementation of ERP systems in public universities has been dependent on availability of adequate mix of internal and external human resources. In implementing ERP systems in public universities, the main influential factors affecting implementation strategies undertaken include project cost overruns where initial budgets have fallen short of total implementation costs.

ERP Based Communication

Study findings indicate that performance monitoring information in ERP application management strategies was effective. This is aimed at providing seamless integration of implemented system with institutional functions. In addition, the study findings point out that effective monitoring for availability

in ERP application management is carried out. The challenge remains in uncertainty of communication processes carried out through ERP platforms in public universities. With communication interfaces experiencing frequent problems, this hurts reliability of communication processes over ERP platforms in public universities. The study concluded that successful implementation of ERP systems in public universities requires consideration of system attributes, communication interfaces and service delivery functionalities of deployed enterprise systems.

RESEARCH CONCLUSION

To achieve desired productivity of enterprise systems, technical improvements and reduction of operational costs is required. From the study, this can be done by aligning institutional functions to functionality of enterprise system under implementation. This resonates with observations by Sylvestre, (2004) on the need for examining system characteristics and aligning these with functional areas of the institution in need of automation. From the study, public universities should prepare for implementation of ERP systems by aligning their functional areas to meet ease of automation and integration of their operations with implemented enterprise systems. This would help in choosing an ERP implementation type and customization that not only meets institutional functional needs but also budgetary constraints of the respective institution. In cognizance of recommendations by Pollock (2004), public universities should focus on restructuring their functional elements for ease of implementation of enterprise systems.

To achieve desired levels of service delivery in institutions, use of adequate mix of both internal and external expertise is required in implementation of enterprise systems by public universities. This ensures that ERP projects undertaken are assured of continuity to completion while maintaining desired functionality. As brought out in study findings on table 4.6, need for an adequate mix of both internal and external human resources to lead implementation initiatives is a critical concern. With a mean deviation of 2.3544 which is indicative of a critical success factor for successful ERP system based service delivery, public universities should provide relevant training for their internal staff while sustaining adequate technical support from external staff in implementing their enterprise system. This helps in ease of technology transfer and capacity building for staff tasked with implementation of enterprise systems in respective institutions.

The above findings resonate with arguments by Leon (2008), which indicate that ERP system implementation is a people project and not a technology project. This was evident from the findings of the study where inadequate internal and external human resources were cited as critical factors affecting implementation of enterprise systems in sampled public universities.

From the study, high levels uncertainty in institutional connectivity was decried by most respondents. With a mean deviation of 2.3165 from table 4.7, which is indicative of the high frequency of problems experienced with communication interfaces, institutions need to address connectivity issues to be in a position to provide uninterrupted communication and seamless connectivity over enterprise systems platforms implemented. The above findings fail to meet recommendations by Sullivan and Bozeman (2010) which foresee increased efficiency, process improvements and improved resource management from implementation of enterprise systems in institutions. Despite these setbacks, there have been significant efforts towards seamless connectivity of departments in public universities using enterprise systems.

RECOMMENDATIONS

The study recommends continuous review of ERP implementation efforts in public universities. This should be done to provide up-to-date literature on progress and experiences in various institutions for

information and contribution to the body of knowledge in use of enterprise systems in higher education in Kenya. Continuous review should be done to avoid stalled as well as abandoned ERP implementation efforts in public universities. This is a worrying trend in implementation of ERP systems in higher education institutions in Kenya. The observations resonate with findings by Huang and Palvia (2001) which point out that literature on use of enterprise systems is lacking in developing countries.

An ERP deployment should be undertaken when sufficient critical success factors are addressed to position an institution favourably in successfully implementing an ERP system. The chosen ERP system by an institution should not only meet present functional requirements of the institution but also provide compatibility with existing systems while providing scalable options for future growth of respective institutions. Use of an adequate mix of internal and external human resources should be taken into consideration to facilitate successful implementation of ERP systems in public universities.

The study further recommends continuous monitoring of communication interfaces conducted over ERP platforms. Preventive maintenance procedures and debugging should be conducted to provide efficiency and reliability and avert would be system downtimes. Implementation of ERP systems should meet improved service delivery needs in respective institutions. Quality of service delivery should be responsive to institutional needs while providing operational advantage to respective institutions.

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IMPACT OF CURVED SHAPED ENERGY DISSIPATERS DOWNSTREAM DIVERSION HEAD STRUCTURES ON THE DISSOLVED OXYGEN CONTENT IN IRRIGATION CANALS & ENHANCEMENT OF IRRIGATION WATER QUALITY

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Abstract

Using energy dissipaters on the soled aprons downstream the head structures is the main technique for accelerating the hydraulic jump formation and dissipating great amount of the residual harmful kinetic energy occurring downstream head structures. In this paper, an experimental study was conducted to investigate some untested shapes of curved dissipaters with different angles of curvature and arrangements from two points of view; The first is to examine its efficiency in dissipating the kinetic water energy. The second is to examine the most effective shape and arrangement obtained from the above maintained step in enriching the flow with dissolved oxygen for enhancement of the irrigation water quality. The study was held in the irrigation and hydraulic laboratory of the Civil department, Faculty of Engineering, Assiut University, using a movable bed tilting channel 20m long, 30cm width, and 50cm height, using 21 types of curved dissipaters with different arrangements as shown in table 1. A total of 660 runs were carried out. Results were analyzed and graphically presented, and simple formulas were provided to evaluate the energy dissipation ratio and the DO concentrations. Results in general show that, the dissipater performance is more tangible in dissipating the residual energy when the curvature is in the opposite direction of flow. Also, the energy loss ratio increases with the increase of curvature angle (θ)*, till it reaches* $(\theta = 120^{o})$*, then it decreases again. The study also shows that, using three rows of dissipaters give nearly the same effect of using four rows concerning both, the relative energy dissipation and dissolved oxygen content. So, it is recommended to use three rows of the curved dissipater with angle of curvature* $(\theta = 120^{o})$ *in the opposite direction of the flow to obtain the maximum percentage of water energy dissipation downstream head structures, and maximum dissolved oxygen content too.*

Keywords: energy dissipation, kinetic water energy, hydraulic jump, curved sill dissipater, water quality, dissolved oxygen.

Nomenclature

V_1 The average velocity at the initial depth;
V_2 The average velocity at the sequent depth;
y_1 The initial depth of jump;
y_2 The sequent depth of jump;
y_c The critical depth of the flow;
z The height of drop;
ρ The density of water;
μ The dynamic viscosity of water; and
θ The end sill angle of curvature
q The discharge per unit width of the flume;
R_{e_1} Reynolds number upstream the jump;
r_1 Radius at the beginning of the jump;
r_2 Radius at the end of the jump;
r_0 The ratio of r2 to r1 the ratio of r2 to r1
S_0 The bed slope of the channel;
V_0 The average velocity U.S. the sluice gate;

F_{e_1} Froude number upstream the jump;
g The gravitational acceleration;
h_s The height of the end sill;
L_B The length of stilling basin;
L_j The length of jump;
L_s The position of end sill from the gate;
L_w The length of the crest;
B The width of the flume;
b The contracted width of the channel;
D The gate opening;
DO The dissolved Oxygen;
E_0 The total flow energy U.S. the sluice gate;
E_1 The total flow energy upstream the jump;
E_2 The total flow energy D.S. the jump;
ΔE The energy loss;

1. Introduction

1.1. Energy dissipation. Flow over spillways or underneath gates have a tremendous amount of potential energy, which is converted into kinetic energy downstream head structures. This energy must be dissipated shortly and safely as near as possible to the head structure to avoid its destructive effect. Using energy dissipaters on the soled apron in the downstream side of the structures was the main technique for accelerating the hydraulic jump formation and dissipating great amount of the residual harmful kinetic energy occurring downstream head structures. So early, many researchers investigated different types, shapes, and arrangements of such dissipaters to evaluate its efficiency in dissipating the water energy and accelerating the forming of the hydraulic jump such as USBR [1], Petreka [2], Habib and Nasser [3], Alikhani et al. [4], Tiwari et al. [5], Bastawy [6], El-Gawhary et al. [7], and Aziz et al. [8]. There are many relations and equations for determining the energy dissipation percentage downstream the head structures such as developed by Wafai [9], [10], Habib [11], [12], Negm et al. [13], Shahmirzadi et al. [14], and Rageh [15] which are reviewed in our previous work(Ashour et al. [16]).

1.2. Irrigation water quality. Currently there is much emphasis on water quality and maintaining water quality parameters in our freshwater hydrosphere (rivers, lakes, and reservoirs). Dissolved oxygen (DO) concentration is one of the most widely cited parameters, since it often used as a good indicator for the quality of water used by humans or serving as a habitat for aquatic flora and fauna. DO is typically measured and reported as concentrations using either mg DO/L of water (mg/L) or percent saturation as the units, Wilson [17]. Rule 64 of the Michigan Water Quality Standards (Part 4 of Act 451), [18] includes minimum concentrations of DO which must be met in surface waters of the state. The variability in DO in rivers is caused by the influences of many factors, and the major influences can be categorized as being either sources or sinks of DO in rivers, Cox [19]. The major sources of DO include: reaeration from the atmosphere; enhanced aeration at weirs and other structures; photosynthetic oxygen production and the introduction of DO from other sources such as tributaries. The main causes of oxygen depletion, or sinks, are: The oxidation of organic material and other; reduced matter in the water column; degassing of oxygen in supersaturated water; respiration by aquatic plants and the oxygen demand exerted by river bed sediments. Since the DO content is a significant indicator for the aeration of the water. Enhancing the water DO content through the aeration is extensively studied in the literature review, Gameson [20] was the first to report on the aeration potential of weirs in rivers. Since then air entrainment and aeration efficiency of hydraulic structures have been studied experimentally by number of investigators, notably Van der Kroon and Schram [21], Apted and Novak [22], Avery and Novak [23], and Nakasone [24]. Recently, Bayler and Bagatur [25], Bayler et al. [26], Emiroglu and Bayler [27], and Ozkan et al.[28]. Investigations have also been reported on the aeration performance of existing hydraulic structures and these are reviewed by Wilhelms et al. [29]. As for the studies done on the direct effect of hydraulic structures on DO concentrations was the study done by El Baradei [30]. But this study investigated the effect of gates on the DO concentration. El Baradei [31] studied the effect of broad crested trapezoidal weirs on the DO concentration at two different water depths. Results showed that installing the weir increased the values of the DO (comparing its upstream side with

the downstream side) by an average of 5.3% comparing all depths. Reviewing the literature review concerning the enhancement of the DO content, proved that very limited researches join between the energy dissipation and the flow enrichment with the DO for improving the quality of water such as Kucukali and Cokgor [32], Kumar and Achanta[33] and , Anandraj[34], who confirmed the positive linear relationship between aeration efficiency and energy loss along the jump as follows:

$$E_{20} = 0.0024\ \omega + 0.0499 \tag{1}$$

To the best of our knowledge, there are no any studies had been done for joining the effect of the shape of the energy dissipaters downstream water structures on the energy dissipation, and the gained quantity of DO which reflected in improving the irrigation water quality as well. So, this study is focused on the study of the untested shapes of curved dissipaters with different angles of curvature and arrangements from two points of view;

- The first is to examine its efficiency in dissipating the kinetic water energy;
- The second is to examine the most effective shape, and arrangement obtained from the above maintained step in enrichment the flow with dissolved oxygen for the enhancement of the irrigation water quality.

2. Dimensional analysis

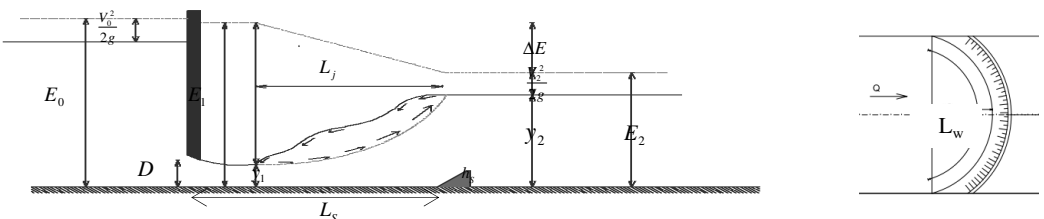


Fig. 1. Definition sketch for forced hydraulic jump with curved end sill.

Referring to Fig.1, the following functional form for the dissipation energy in rectangular basin with curved sill dissipaters could be expressed as follows:

$$\Delta E = \phi(\rho, \mu, g, D, y_1, y_2, L_W, L_j, L_S, h_s, \theta, q) \tag{2}$$

Since h_s and L_s were kept constant throughout the experimental program, they will be removed from Eq. (2). Also, the effect of viscosity is assumed of secondary importance in estimating the energy dissipation parameters as the flow is mainly gravitational, and therefore, the effect of Reynolds number, R_e, can be neglected; then, these variables can be grouped into the following non-dimensional parameters by use of dimensional analysis:

$$\frac{\Delta E}{y_1} = \phi\left(\frac{y_2}{y_1}, \frac{L_j}{y_1}, \frac{L_w}{y_1}, \theta, F_{e_1}\right) \tag{3}$$

3. Experimental set-up

Experiments were performed in a recirculation, rectangular open tilting flume at the Irrigation and Hydraulic laboratory of Civil Engineering Department at Assiut University, Egypt. As shown in Fig. 2, the flume is 17.50 m. long, 0.30 m. wide and 0.50 m. depth with adjustable slope. Measurements of water depth were taking using an electrical point gauge mounted on an aluminum frame over the channel, so it could be moved longitudinally and transversely over any point on the channel bed. The gauge was equipped with a vernier, readable to reach an accuracy of about 0.10 mm. Measurements of the DO concentration were measured using VWRbrand Dissolve Oxygen Meter Model 4000. A sluice gate made of aluminum was used as a heading-up structure. A tail gate was located at the end of the channel to control the downstream water depth.

4. Experimental approach

Twenty one different shapes of end sill were tested as energy dissipaters downstream the sluice gate model. Detailed dimensions and arrangements of the tested energy dissipaters models are

shown in table. 1. These models were made of painted timber to be placed separately on the flume bed downstream the sluice gate. 660 runs were conducted and were categorized into three sets of experiments. The first set of experimental runs was carried out on downstream floor without energy dissipaters. This set included 30 runs and was considered as a reference in order to estimate the effect of using the tested energy dissipaters. The second set of experimental runs, was carried out using twelve types of curved dissipaters having a curvature angle of 60,75,90,120, 150, and180 degree, in addition to the straight one as a reference. This set included 390 runs. The third set of experimental runs, was carried out using the most effective shape obtained from the above maintained step as one continuous row or more or as staggered separate dissipaters in one or more rows, to examine its efficiency in dissipating water energy, and at the same time its role in enriching the flow with oxygen through the great aeration of the flow within the dissipating energy distance downstream head structure. This set included 240 runs. In each test, six different discharges between 4.75 and 25.21 L/s were used with five gate openings between 20 and 50mm, the position of the models was fixed so that $\left[\frac{L_s}{b} = 5.83\right]$, and the height of the models was fixed so that $\left[\frac{h_s}{h} = 0.11\right]$ as recommended by Wafaie [12-13].

5. Experimental procedures

Runs were started with the models fixed separately on the flume bed downstream of the sluice gate. The storage tank was filled with low dissolved oxygen content water (drainage water), to obtain tangible measured values of DO before and after using the tested dissipaters. The intake valve of feeding pipeline was opened slowly to give a definite value of discharge through adjusting both the intake valve and the water manometer reading. The downstream tail gate was adjusted to obtain the free flow conditions, after a period of about 20 to 30 minutes. The measurements of the water depths $[y_0, y_1, y_2]$ were made in three longitudinal axis of the flume at b/4, b/2, and 3b/4, in which b is the flume width, and then the average value were determined. The jump length were measured then by the use of horizontal scale. During the experiments, DO measurements upstream and downstream of the curved dissipater were taken using a calibrated portable VWRbrand Dissolve Oxygen Meter Model 4000 at the locations identified in Fig. 3, at every position three measurements were taken, near to the water surface , near to the bed of flume and at the mid-water depth. The DO meter was calibrated daily prior the use, by the air calibration method. Calibration procedures followed those recommended by the manufacturer. The calibration was performed in humid air under ambient conditions.

Table 1. The tested configurations of curved sill dissipaters

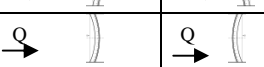
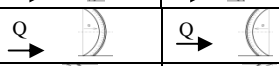
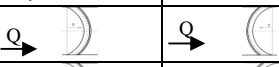
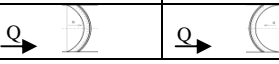
NO.	Shape	Angle of curvature	Length of the crest	Direction of curvature with respect to the main flow direction
1		Zero	30 cm	
2, 3		60^o	31.42 cm	
4, 5		75^o	32.25 cm	
6, 7		90^o	33.32 cm	
8, 9		120^o	36.28 cm	
10, 11		150^o	40.66 cm	
12, 13		180^o	47.12 cm	

Table 2. Comparison between the measured relative energy dissipation for the studied models

Angle of curvature	In the direction of flow	In the opposite direction of flow	In the direction of flow	In the opposite direction of flow
60	0.60-11.40	0.70-13.00	3.30-26.70	5.00-28.90
75	0.43-14.90	2.55-18.30	3.50-27.40	5.20-32.10
90	2.30-20.10	4.00-24.15	5.00-33.40	6.70-36.30
120	**3.50-24.70**	**5.70-30.40**	**9.20-36.55**	**13.0-42.55**
150	0.42-16.11	3.16-19.30	5.16-30.60	9.00-34.10
180	0.17-10.90	0.11-13.60	2.50-24.70	5.05-27.75

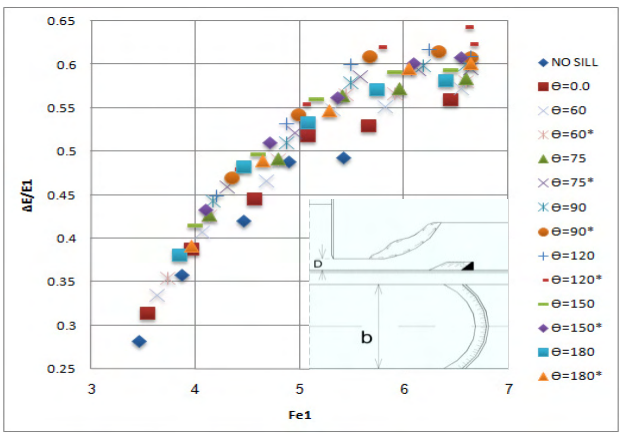


Fig. 4. Relationship between Relative energy loss and Froude Number for all under study sill dissipaters curvature at (D/b=1/10).

Relationships between the values of relative energy loss $\left(\frac{\Delta E}{E_1}\right)$ and the angle of dissipater curvature for the under study curved sill dissipaters are illustrated as shown in fig.5 for example. From this figure, it is clear that, the energy loss ratio $\left(\frac{\Delta E}{E_1}\right)$ increases with the increase of curvature angle (θ), till it reaches $(\theta = 120^{o})$, then it decreases. For all angles of dissipater curvature (θ), the relative energy loss $\left(\frac{\Delta E}{E_1}\right)$ increase with the increase of the inflow Froude number (F_{e_1}). Also, It is clear that the difference in relative energy loss has a maximum value at $(F_{e_1} = 4.0)$, while at $(F_{e_1} = 6.0)$, the difference in relative energy loss is minimum. In addition, the results show that, the sill dissipater models with angles of curvature in the opposite direction of the flow is better than that with the angles of curvature in the same direction of the flow. The relative energy loss $\left(\frac{\Delta E}{E_1}\right)$ for sill dissipater $(\theta = 120^{o})$, is larger than the relative energy loss $\left(\frac{\Delta E}{E_1}\right)$ for all other dissipaters with other values of angle of curvature (θ).

more rows didn't give any increase in the relative energy loss. The amount of increase in the relative energy loss for different rows number than the case of regular straight dissipater are given in table 5.

Table 5. Comparison of the measurable relative energy dissipation for the different rows number.

Number of rows	One row		Two rows		Three rows		Four rows	
	Continuous	staggered separate	Continuous	staggered separate	Continuous	staggered separate	Continuous	staggered separate
The amount of increase in the relative energy loss	5.70-30.40	6.70-31.15	8.40-33.30	8.75-34.20	9.00-34.90	9.30-36.00	9.30-35.15	9.60-33.30

Figure 10, shows the relation between the relative energy loss $\left(\frac{\Delta E}{E_1}\right)$ and the number of rows for the best curved dissipater $(\theta = 120^{\circ})$ in the opposite direction of flow and for different gate openings. From this figure, it is clear that, the relative energy loss $\left(\frac{\Delta E}{E_1}\right)$ increases with increasing of the rows number. For further increases of rows number, the differences of $\left(\frac{\Delta E}{E_1}\right)$ for different flow condition decreases. In addition, for the same value of (Q), the case of (number of rows =4) have the best performance in increasing the relative energy loss $\left(\frac{\Delta E}{E_1}\right)$ for all other cases. While, the case of (number of rows =1) have the worst results of $\left(\frac{\Delta E}{E_1}\right)$. Also, using three rows of dissipaters give nearly the same effect of using four rows for increasing the relative energy dissipation. So, it is recommended to use three rows of the curved dissipater with angle of curvature $(\theta = 120^{\circ})$ in the opposite direction of the flow to obtain the maximum percentage of water energy dissipation downstream head structures.

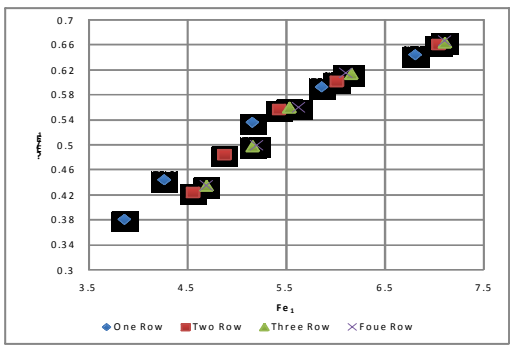


Fig. 9. Relationship between relative energy loss and Froude Number for the all study rows numbers at (D/b=1/12).

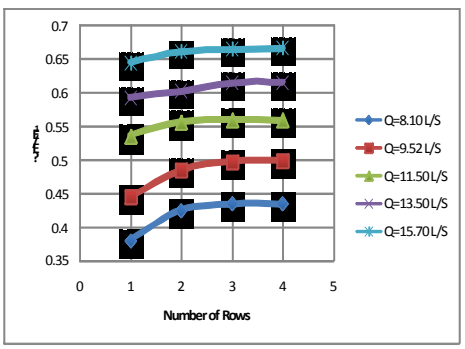


Fig. 10. Relationship between Relative energy loss and number of rows for different examined discharges at (D/b=1/12).

Also, the best equation predicting the relative energy loss for the best curved dissipater $(\theta = 120^{\circ})$ in the opposite direction of flow for rows number not exceed four rows, can be put in the following form.

$$\frac{\Delta E}{E_1} = 0.09289 - 0.00113 * N + 0.08306 * (F_{e_1}) \quad (5)$$

Eq. (5) was valid for the used flow conditions with correlation R2 equal to 0.921.

6.3. Irrigation water quality. Experimental results were represented graphically to study the efficiency of the most effective energy dissipater $(\theta = 120^{\circ})$ in the opposite direction of flow in enrichment of the flow with DO along the stilling basin downstream head structures. Fig. 11 for example, shows the DO concentration observed during experiments as a function of horizontal distance from head structure, vertical depths of water and discharge for different rows number and for different gate opening. From this figure, it is clear that, DO concentrations increases with increasing of rows number. For further increases of rows number, the differences of DO concentrations for different flow condition decreases. For the same value of (Q), the case of (number of rows =4) have the best performance in increasing the DO concentrations for all other cases. While, the case of (number of rows =1) have the worst results of DO concentrations . Also, it is not recommended to use more than three rows of energy dissipaters, because more rows didn't give any increase in the DO concentrations. The performance of all cases of rows number in increasing the DO concentrations are listed in table 6.

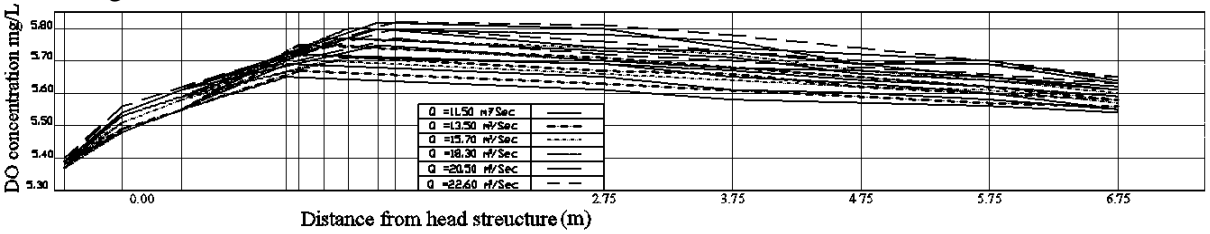


Fig. 11. Variation in Dissolved Oxygen concentration with horizontal distance from head structure for case of (Rows number = 3) of Curved dissipater (angle of curvature = 120) in the opposite direction of flow, at (D/b = 1/10).

Table 6. Comparison of the measurable Do for the different rows number

Number of rows	One row		Two rows		Three rows		Four rows	
The mount of increase in DO concentration for different rows numbers more than that obtained without using any dissipaters	Continuous	staggered separate	Continuous	staggered separate	Continuous	staggered separate	Continuous	staggered separate
	1.10-4.70	1.60-5.80	1.80-5.10	2.20-6.30	2.20-5.60	2.20-6.70	2.40-5.90	2.50-7.20

The results revealed that, the effect of curved dissipater in increasing the values of DO concentrations at the downstream side of the head structure as shown in fig .12 for example. This increasing effect could be seen particularly at the end of the hydraulic jump. Actually at the upstream side of the head structure the DO concentration was low, as the water flew under the head structure, the DO starts to increase till it reaches its peak at the end of the jump. These results could be interpreted as follows: as the water flows under the head structure and goes through the hydraulic jump it will be aerated due to the turbulence that the jump creates and thus the DO values increase. As the water reaches the end of the jump; it would had been went through the utter most effect of the jump aeration and thus the DO values at the end of the jump are the highest. After the end of the jump and its effect the DO in water decreases again but still it remains higher than the upstream side of the head structure. When comparing the DO concentrations at different depths. It was found that at surface of water, DO levels were higher than at the mid- depth of water and abed of flume . This is due to the fact that water at the higher depth is nearer to surface (air-water interface surface) than at the lower depth.

- The curvature of dissipaters in the opposite direction of the flow gives more efficient results in dissipating the energy with about 8.0 %, than that with the curvature in the same direction of the flow.
- Staggered discontinues rows of dissipaters is more efficient than continues rows, by about 7.0 %.
- Using more than three rows of dissipaters has no effect in dissipating water energy.
- The maximum efficiency of reaching the flow with DO was obtained with using four rows of curved dissipaters with angle of curvature equals 120 degrees in the opposite direction of the flow.
- The following equation is introduced for estimating the percentage of dissipating the water energy at any distance downstream the head structure :

$$\frac{\Delta E}{E_1} = 0.09289 - 0.00113 * N + 0.08306 * (F_{e_1}) \quad (5)$$

- For estimating the gained percentage of DO at any distance downstream head structure, the following equation is introduced :

$$Log(D_O) = 1.1949 \text{ Log (X)} + 0.0073 \text{ Log (Y)} - 0.2057 \text{ (X)} + 0.8778 \quad (6)$$

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VOWEL HARMONY IN KITHARAKA

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ABSTRACT
Kitharaka is a central Kenya Bantu language - a group of languages that Guthrie (1970/71) designated as E50 and which Bennet's (1977, 1985) refers to as Thagicu languages. The languages of the sub-family comprise Kitharaka, Kikuyu, Kikamba, Kiembu and Kimeru. Kitharaka, as well as the other languages of the sub-family have vowel harmony. In this paper I examine vowel harmony as a widespread phonological process and discuss its nature in Kitharaka. I show the similarities that Kitharaka vowel harmony shares with other languages as well as the differences that sets apart Kitharaka vowel harmony from the harmony of other languages.

1. INTRODUCTION

Katamba (1984: 257) comments that:

> In some languages, vowels occurring in some specified domain, which is usually the word, must share some phonetic property or properties. Such languages are said to have vowel harmony.

On his part, A.C. Baker (2009:2) observes that:

> Vowel harmony interests a wide range of phonologists for a number of reasons. It is widespread among the world's languages, but nowhere near universal. It is a phonotactic constraint that is nonetheless violated by many roots in vowel harmony languages, but it's also an active phonological process that causes alternations.

This phonological phenomenon that is found in many languages of the world is also found in Kitharaka as well as in other Central Kenya Bantu languages, namely, Kikuyu, Kikamba, Kiembu and Kimeru (Wa Mberia,1993). The presence of the phonological phenomenon supports the contention by Clements (1976) and Kiparsky (1981) quoted in Finley and Bedecker (2008). Finley and Bedecker observe that "… vowel harmony is an extremely common phonological that occurs in a wide range of language families (e.g., Bantu, Nilotic, Romance, Urulic) (Clements, 1976; Kiparsky, 1981). Furthermore, the vowel harmony found in Kitharaka is of the canonical type, that is, harmony that spreads from vowel to vowel without affecting or being affected by intervening consonants (Mahanta, 2007).

Kitharaka has two types of vowel harmony (Wa Mberia, (1993). The first type occurs between the vowels of the pre-prefixes and those of the following prefix. Furthermore, in the demonstrative adjectives, each of which consists of a noun class prefix and an adjectival root, the vowels of the two morphemes are identical.

The second type of vowel harmony in Kitharaka operates between the verb roots and some of the verb suffixes such as the applicative, stative, and reversive morphemes. This vowel harmony into which the seven vowels of Kitharaka divide themselves into tense and lax sub-sets, is determined by the vowel of the root.

Whereas the first type of vowel harmony is a morphological phenomenon, the second type results from the operation of a phonological process. The former is occasioned by morphological processes such as reduplication; the later is the outcome of assimilation. Just as Kitharaka has vowel harmony, so do the other Central Kenya Bantu languages. Specifically, the vowel harmony found in Kitharaka and other Central Kenya Bantu languages, or as Bennett refers to them, Thagicu languages, is of the tense-lax opposition. This kind of harmony is the same phenomenon as covered-uncovered vowel opposition leading to the conclusion that the Chomsky and Halle dichotomy between the two is untenable (Stevens et al 1969).

2. MORPHOLOGICAL VOWEL HARMONY

Reconstructions of the noun classes in Bantu have posited between nineteen and twenty three classes for the family. Kitharaka has only seventeen noun classes ranging from Class 1 to Class 17. The same situation obtains for all the other Thagicu languages. They have historically lost all the classes above class 17. The class sentential agreement displays morphological vowel harmony.

Kitharaka has compulsory "preprefixes" in the attributive adjectives for noun classes 1, 3 and 4. These "preprefixes" have a vowel that is identical to the vowel of the prefix. The following examples demonstrate the phenomenon:

(1)

Class	Preprefix	Prefix	Adjectival Stem	Gloss
1	o	mo	raja	tall / long
3	o	mo	raja	tall/long
4	e	me	raja	tall/long

Demonstrative pronouns also exhibit agreement between two vowels. Thus:

(2)

Noun Class	Demonstrative pronoun	Example	Gloss
1	oyo	mwarimↃ oyo	"This teacher"
2	ßaßa	aciari ßaßa	"These parents"
3	oyo	moramba oyo	"This baobab tree"
4	ino	meti enↃ	"These trees"
5	rere	ekↃmɛ rere	"This egg"
6	mama	makiɲa mama	"These footprints"
7	keke	ɤetanda ɤeke	"This bed"
8	ßißi	ituɤe ßißi	"These poles"
9	enↃ	ɲↃmba enↃ	"This house"
10	inↃ	ŋkare inↃ	"This vehicle"
11	roro	roriɤi roro	"This thread"
12	kaka	ka: na ɤa:ka	"This child"
13	toto	twana toto	"These children"
14	ßoßo	otↃnga ßoßo	"This wealth"
15	koko	koΔↃma ɤoko	"This reading/ learning"
16	aɣa	ßanto aɤa	"This (specific) place"
17	koko	ɤonto ɤoko	"This (genera) place

As evidenced by the data in (1) and (2) above, Kitharaka has either reduplication of the syllable of the pronoun as whole or a reduplication of only the vowel. Thus, entries such as βaβa, rere, mama, keke, βiβi, roro, kaka, toto, βoβo, γoko have the first syllable reduplicated. In the forms oyo, and aγa, the vowels [o] and [a] are respectfully reduplicated. The only exceptions to the above two scenarios are /enↃ/ and /inↃ/ for Classes 9 and 10 respectively.

The type of vowel harmony exhibited by the data in (1) and (2) is simple in the sense that the harmonizing vowels are identical to one another. It appears that this type of harmony results from morpheme-copying[4]. It is therefore an outcome of a morphological rather than a phonological process. In the data in (1) and (2) the syllables correspond to the morpheme. In the Classes 1, 3 and 4 attributive adjectives, class marker morpheme has lost historically lost consonant in the "pre-prefix".

3. PHONOLOGICAL VOWEL HARMONY

The second type of vowel harmony is found in the extended verbs. It is much more complex than what has been described above. Let us consider the data in (3) below where we show the underlying representation (U.R.) and the surface representation (S.R):

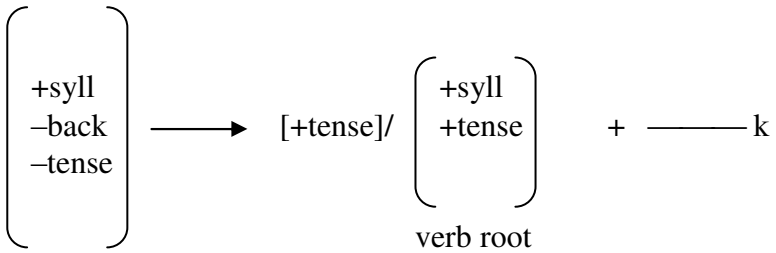
(3)

U.R.	S.R.	Gloss
/iŋg+ek+a/	[iŋgeka]	possible to close
/tan+ek+a/	[taneka)	possible to circumcise
/tum+ek+a/	[tumeka)	possible to sew/weave
/rom+eka+/	[romeka)	possible to cultivate
/rↃɤ+ek+a/	[rↃɤɛka]	possible to bewitch
/tɛγ+ek+a/	[tɛγɛka]	possible to trap

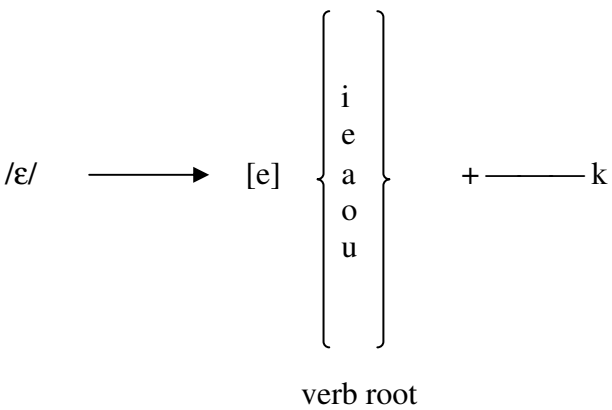
According to these data, the stative morpheme has two surface realization, that is [ek] and [ɛk]. The data shows that [ek] occurs in verbs that have /u/, /a/, /o/, or /e/ in the root. On the other hand, [ɛk] occurs in verbs whose roots have /ɛ/ or /Ↄ/. Phonetically, /i, a, u, o, e/ are tense vowels whereas /ɛ/ and /Ↄ/ are lax. Thus, if the root of the verb has a tense vowel, it takes the stative allomorph that has a tense vowel. On the other hand, if the root has a lax vowel, it takes the allomorph with a lax vowel. In other words, the vowel harmony exhibited by the data is determined by the value of the feature [TENSE] in the verb root.

According to Generative Phonology, for an allomorph to qualify as the underlying form, it has to be shown that it occurs in a context that is free from a conditioning environment. In the specific instances of [ek] and [ɛk], the underlying form should be shown to occur with roots that do not have a vowel. In all the data considered, whereas [ek] is found only in verbs which have tense vowels in the roots, [ɛk] occasionally occurs in verbs that do not have any vowels in the roots. [ek] is found, for instance, in stative [tɛka] (infinitive: ko-t-a "to throw away"). Under these circumstances, it is plausible to conclude that the stative morpheme is {k} and that [ek] is derived from it through a phonological process. The process is triggered off by the presence of a tense vowel in the verb root. It may be formulated as (4) below:

feature [TENSE] between the vowel of the root and that of the verb extension. The applicative harmony rule, however, has /r/ where the stative rule has /k/. Thus:



that is,



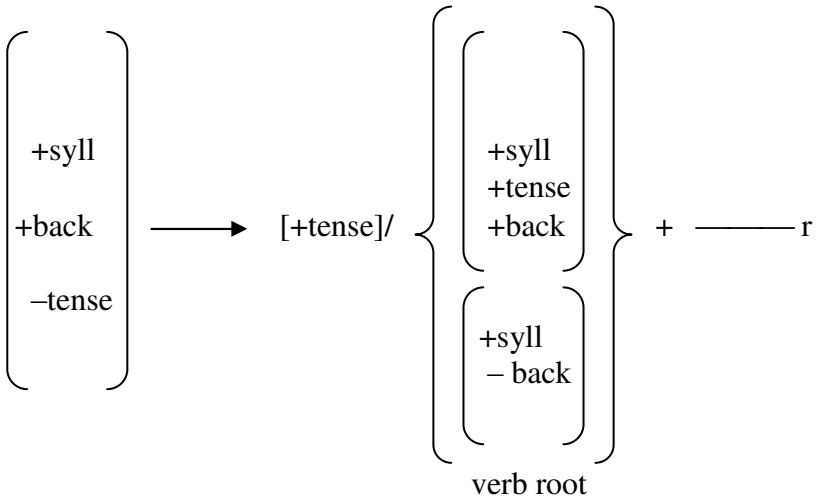
The third verb extension affected by vowel harmony is the reversive morpheme. It has two variants, [or] and [ɔr], as shown in the following data:

Conversive.

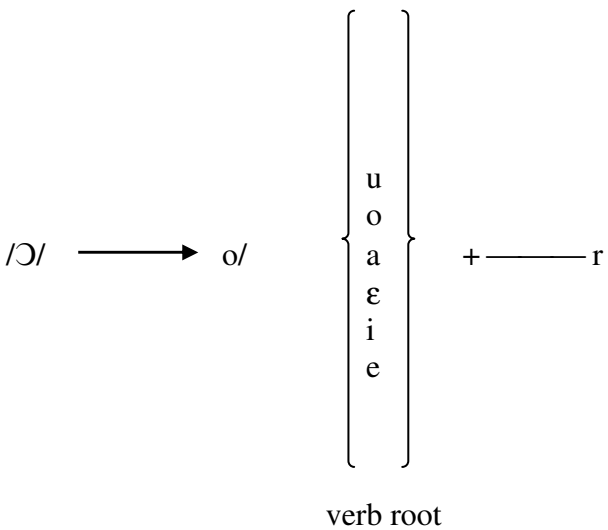
[iŋgora]	open
[tomora]	unweave/unsew
[tɛɤora]	set off (a trap)
[rɔɤɔra]	treat a bewitched patient
[tanora]	reverse circumcision.

According to these data [ɔr] occurs in roots that have /ɔ/ whereas [or] is found elsewhere. Unlike in the case of stative and applicative morphemes where our conclusions on the underlying variants were made on the basis of the variants occurring in roots without vowels, all the verbs that we have analysed for the reversive extension contain vowels in their roots. In the circumstances, there does not seen to be any empirical grounds on which to decide whether [ɔr] or [or] is the underlying form. However, in our view it is more plausible to take [ɔr] as the underlying variant on account of analogy with [ɛk] and [ɛr] (which as we have argued above are the underlying stative and applicative morphemes respectively than to posit [or] as the underlying form. Following this line of reasoning the underlying reversive morpheme is {ɔr}, surfacing as [ɔr] when the root has /ɔ/ and or [or] elsewhere.

The rule that governs this harmony may be formulated as follows:



that is,



In the stative and applicative extensions the vowel of the extension agrees with the vowel of the root for the feature [TENSE]. This situation does not obtain in the reversive extension where the harmony is between the [Ɔ] of the extension and the [Ɔ] of the root on the one hand, and [o] of the extension and /i, e, ɛ a, o, u/ of the root. In other words, the conditioning environment for the vowel harmony process is broader in the stative and applicative verb extensions than it is in the reversive verb forms.

4. CONLUSION

In discussing vowel harmony Finley and Bedecker (2009) observe that directionality is an important issue because vowel harmony can be described either directional or non-directional. In the non-directional harmony, the feature spreads from a conditioning vowel in the stem outwards to the right, or outwards to the left, or to both the right and the left. They note that when it is directional, a vowel feature spreads in one direction from the conditioning vowel to the target vowel. Thus, the spreading of the feature may be from the rightmost vowel of the morphological stem to a target vowel to the left or

from the leftmost vowel of the morphological stem to the left of a target vowel to the right. Quoting Hyman (2002), they note that, in the directional harmony, there appears preference or a bias towards the right to left feature spreading.

From the illustrations of Kitharaka data presented above, Kitharaka has a directional vowel harmony. Moreover, unlike the bias shown by languages, in Kitharaka the harmony spreads from the a conditioning vowel in the root in left to right direction.

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Wiring Kenyan Languages for the Global Virtual Age: An audit of the Human Language Technology Resources

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Abstract

Whereas we recognize the advancement of computing and internet technologies over the years and its impact in the areas of health, education, government, etc., there is increasing cognizance that the languages used in these technologies will have a far reaching impact in terms of accessibility and usability by a wider audience. European languages and specifically English is considered the lingua franca of computing and the Internet due to the vast amount of language resources available in these languages. Does this therefore exacerbate the language and technology gap, especially in regards to African languages?

This research is motivated by this question and begins to tackle a strand of the overarching language technology issue by auditing the human language technologies for Kenyan languages. The research uses the Basic Language Resource Kit (BLARK) to do the inventory. This method has been successfully used to conduct language resources surveys in other countries.

Introduction

Discourse over the use of local languages as the primary instructional language for early childhood education and generally pre-primary education has incrementally taken center-stage in Education policy matters in Kenya with renewed advocacy coming from the ministry of education (Omwenga, 2014). Moreover, research indicates that the use of local languages as a medium of instruction in the formative years offers many advantages because it ensures the pupils have seamless learning at the home and school environments. (Piper, 2010). The use of local languages as media of instruction in education and development in Africa is widely acknowledged by several African governments (Prah, 2002: 9). However, implementation has not been without challenges, including the lack of national policy on language and technology, and competition from highly resourced languages like English, French, Portuguese, Arabic, etc. Besides, English is the most highly resourced language and it is considered the lingua-franca of internet technology. These languages have been well documented over the years with properly defined grammars, unlike the local languages most of which have poorly defined and undocumented grammars and dictionaries (Ombui & Wagacha, 2007).

Advances in technology over the years including higher processing speeds and larger memory capacity of computers have facilitated further research in the application of computers to support decision-making in various disciplines and domains ranging from health, security, agriculture, education, governance etc. In all these areas, data capturing, processing, storage and final display must be in a language that is meaningful and understood by human beings. Otherwise, there will be a gap between the computing technology and its users. This language gap in technology has led to more specific research under the Human Computer Interaction discipline to address challenges in hardware and software technologies in respect to the use of human languages.

Language technologies research basically falls under natural language processing which is subsequently informed mainly by computer science and linguistic efforts. However, these two efforts are often sub optimized from the beginning as each group works independently in pushing their

agenda at the expense of the overarching objective of advancing language resources that are informed by and interdependent on both efforts (Grover *et al*., 2009, Binnenpoorte et al., 2002) . These resources include but are not limited to text and speech corpora, lexicons, machine translation, machine learning, speech recognition and synthesis, text summarization, part-of-speech taggers, parsers, annotators, data collection and management tools.

In order to get a good gist of the current work undergoing in terms of Human Language Technology (HLT), a research into existing projects was inevitable. A HLT audit was considered a good starting point for both ongoing and future research into HLT in Kenya.

This research therefore explored the existing research efforts in the area of natural language processing technologies for Kenyan languages and the existing local content on the Internet.

This paper starts by indicating the related work, the methods and tools used to conduct the audit, the results obtained, a conclusion and recommendation for the way forward in regard to the future of HLT in Kenya.

Related Work

Research efforts into existing Human Language Technologies are not new because some countries have already done their Human Language Technology-audits. Some of the well documented HLT audits include: the Dutch HLT survey (Binnenpoorte et al., 2002), Bulgarian (Simov et al., 2004), Arabic HLT (Maegaard et al.: 2006, 2009), Swedish (Elenius et al., 2008), and South African HLT (Grover et al., 2010).

The Dutch HLT survey, just like the other surveys, used the Basic Language Resource Kit (BLaRK) to do its language resource inventory. Their BLaRK had two main categories i.e. Language technology and Speech technology components each of which had two subcategories consisting of Modules and Data resources which were further subjected to an evaluation criteria. The criteria consisted of a checklist that included: availability of the components on the Internet, on Literature and information from actors in the HLT field; reusability, adaptability, extendibility, and compatibility with standards, among others.

In the South African case, the evaluation criteria for HLT was based on the amount of research, resources and technologies developed and available in each of the eleven official languages that were studied. Moreover, this resulted in the identification of inventory gaps which subsequently informed strategic planning in regards to funding research into specific HLT applications and prioritizing under-resourced languages.

A common goal of HLT audits across these countries was to identify the gaps in BLARK and recommend priority components to be developed to complete the BLARK. In addition, the HLT platforms in these countries serve to strengthen the research, development, and sharing of HLT resources for their languages.

Methodology

For the work we are reporting a case study of two universities: University of Nairobi (public) and Africa Nazarene University (private) were used to evaluate the research done in HLT over the past ten years. Apparently, a purposive sampling criterion was used in selecting the public and private universities using the criteria of the oldest and most active computer science programs in the country. Languages: Bantu (6), Nilotic (4), Cushitic (3), and Semitic (1)

A Library survey of HLT projects in the two universities was done at the respective university's department libraries whereby theses and final-year project documents were perused and the language technologies recorded on an excel spreadsheet.

The research adopted a descriptive approach at the beginning whereby an inventory of the available components was recorded as found in the existing literature. Later on, a prescriptive approach was taken whereby the inventory was mapped onto the BLARK instrument (Krauwer, 1998) informed by the South African and Dutch HLT indices for modules and data.

Given the limited funding and time available for the research, the only criterion used on the BLARK was the availability of the HLT components from the existing literature in the thesis and project documents and from Internet sources. This is as shown in Table 1.

An Internet survey was conducted by searching for HLT projects in the country using a web search engine (Google). Here, key words informed by the Basic Language Resource Kit (BLARK) modules were used to do the google search. Moreover, internet sites with data in the local languages were recorded.

Data Analysis was done using MS. Excel spreadsheet whereby the list of modules and data of the existing inventory was entered into the BLaRK instrument developed on the excel spreadsheet and consequently used to identify the gaps in the BLaRK.

Results

Internet search results revealed that approximately 63% of the data on Kenyan local language on the Internet is religious texts, particularly Christian. Parallel text across all the sampled local languages was found with the four spiritual laws and rosary recitation. Moreover, there were Bible chapters in several local languages and some websites that contained basic language learning content. Besides, there were a few encyclopedia projects and dictionaries in some of the local languages.

The modes of the content retrieved from the Internet search were basically HTML texts, PDF documents and audio files. Most of the bible chapters were in PDF format and some in audio files. Moreover, there were video files, especially songs in some of the local languages, retrieved from you-tube.

The library research for language technology projects in the sampled universities indicated that the earliest HLT projects and research were published in 2002 with an upsurge in 2005 and 2006. Majority of these projects were done at the school of computing and informatics, university of Nairobi. These are as shown in Figure 1.

Further Internet research indicated five active HLT projects in the continent of Africa. These included the African Network for Localization (ANLoc,www.africanlocalisation.net) headed by Donald Z. Osborn, USA; the Zuza Software Foundation (www.translate.org.za) in South Africa headed by Mr. Dwayne Bailey; the Kamusi Project International, headed by Dr. Martin Benjamin at Switzerland, the African Languages Technology Initiative headed by Dr. Tunde Adegbola from Lagos, Nigeria, and the African Language Technologies (AfLaT) project headed by Dr. Guy De Pauw from the University of Antwerp, Belgium. Apparently, there was no internet search result for any HLT forum for Kenyan languages.

MODULE/Tool	**AVAILABILITY**	**LANGUAGES**
Speech Recognition, LMS	1	
Text-to-Speech	4	Gikuyu, Dholuo, Swahili
Language Translation	4	Ekegusii, Swahili, Akamba, Gikuyu
Part-of-Speech tagging	2	Akamba
Diacritic correction	1	Gikuyu
Compiler	1	Swahili
Dictation System	1	Swahili
Morphological analysis	1	Swahili
Parsers and Grammars	1	Swahili
Word-meaning disambiguation	1	Swahili
DATA	**AVAILABILITY**	**LANGUAGES**
Text Corpora	3	Ekegusii, Gikuyu, Dholuo
Speech Corpora	Segments	Swahili, Gikuyu
Parallel Corpora	Select Bible Chapters	Swahili, Ekegusii, Gikuyu, Dholuo, Luhya(Bukusu), Kimeru, Kigiriama, Kalenjin, Maasai, Turkana, Somali, Kamba, Oromo
Online Dictionaries & Thesaurus	3	Ekegusii, Swahili, Gikuyu

Table 1: HLT Component Index for Modules and Data

Conclusion

Generally, there were lots of data resources about the local Kenyan languages including history, culture, economic activities, religious activities, education etc. However, most of the websites surveyed generally had minimal content in the Kenyan languages themselves while using English. Moreover, research projects into Kenyan and generally African languages were not only done by

universities and researchers from the West, but also solely funded by grants from the west. Apparently, every funder seeks and expects the research to primarily meet their specific interests which may not be of fundamental interest to the subjects of the research. It is therefore important that research into Kenyan languages and generally African languages should not only be primarily investigated by African researchers but heavily funded by African governments to serve specific interest and needs of African languages and people.

The level of basic language resources and technologies for Kenyan languages is very low as indicated by the 33.3% of BLaRK. Further, this indicates the low number of research activities on human language technologies in Kenyan universities. Moreover, a lack of online HLT forums is a clear indicator of little and segmented research on HLT in the country.

This research is the first of its kind based on BLARK for the Kenyan languages. Publication of these results will offer an excellent platform for researchers to not only be informed of what has been done but more importantly to offer collaboration opportunities to do further research and avoid duplication in HLT research and development efforts.

Generally, the most resourced local language in Kenya, apart from Swahili, is the Gikuyu with several online resources including corpora, part-of-speech tagger, text-to-speech modules, automatic diacritic applications, machine translation, and video content. The other languages covered in this research had less than five HLT components available.

Apparently, most of the published HLT research on African languages has been primarily sponsored and headed by non-Africans. This should be a big challenge for African governments to fund research and development of HLT efforts to address their own unique challenges and interests, just as any funder would. Moreover, the African governments could therefore help prioritize research and development efforts on the basic language and technology resources for their vast local languages to enable national development.

Recommendations

The field on HLT is multidisciplinary and requires concerted effort of Computer Science, Linguistics and other disciplines like Psychology in order to be better understood and consequently address the existing HLT challenges exhaustively. Unfortunately the predominant culture of operating in silos in higher education research exacerbates these efforts. Researcher collaboration across these disciplines is imperative to the success of HLT efforts. Besides, the HLT platforms can help bridge the academia-industry relationships and expediting research and development of well informed and sustainable HLT solutions. Moreover, there is need to establish a HLT online forum to help coordinate, prioritize and reduce duplication of work in the HLT field in Kenya.

With the rise of new, faster and affordable collaboration and social networking technologies, it is about time that volunteer models e.g. Crowd-sourcing technologies be explored for data collection to add to the low data warehouse of Kenyan and African language content i.e. Data or content developed by the natives and in the native languages.

Despite the limited research funding, personnel and time expended in this research, it did break the ground in efforts towards an inventory of HLT in the country. Nonetheless, there is need for a large scale research on HLT in the country that will include field surveys , questionnaires and other methods to cover more if not all Kenyan languages. Moreover, the research should include more HLT participants from industry and academia in order to help build consensus on the country's component index that will build an exhaustive BLARK audit. Besides, the relevant government

agencies need to get involved in order to benefit from the results of the audit exercise which will inform policy making on matters related to HLT in the country.

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On A New Sequence Space of Non-Absolute Type and Inclusion Relations

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Abstract : *In this paper, we introduce the space* $\ell_\infty(\Delta_u^\lambda)$*, which is BK-spaces of non-absolute type and prove that* $\ell_\infty(\Delta_u^\lambda)$ *is linearly isomorphic to the* ℓ_∞*, where* $\lambda=(\lambda_k)_{k=0}^\infty$ *is a strictly increasing sequence of positive reals tending to* ∞*. We also give some inclusion relations.*

Keywords: Sequence spaces of non-absolute type, *BK*-space, Difference Sequence Spaces.

2010 Mathematics Subject Classification: 46A45,46B20

1. Introduction

Let w denote the spaces of all sequences (real or complex). A sequence space is defined to be linear space of real or complex number.

Let X be a sequence space. If X is a Banach space and

$$\tau_k : X \to C \ , \ \tau_k(x) = x_k \ (k = 1,2,3...)$$

is a continuous for all k , X is called a *BK*-space.

We shall write ℓ_∞, c and c_0 for the sequence spaces of all bounded, convergent and null sequences, respectively, which are *BK*-spaces with the same norm given by

$$\|x\|_\infty = \sup_k |x_k|$$

for all $k \in N$.

The notion of difference sequence spaces was introduced by Kızmaz [1] as follows:

$$\ell_\infty(\Delta) = \{x \in w : \Delta x \in \ell_\infty\},$$

$$c(\Delta) = \{x \in w : \Delta x \in c\},$$

$$c_0(\Delta) = \{x \in w : \Delta x \in c_0\}.$$

Further more, he proved these spaces are *BK*-spaces with norm given by

$$\|x\|_\infty = |x_1| + \|\Delta x\|_\infty .$$

M.Mursaleenand A.K.Noman [5] introduced the sequence spaces ℓ_∞^λ, c^λ and c_0^λ as the sets of all $\lambda-bounded$, $\lambda-convergent$ and $\lambda-null$ sequences, respectively, that is

$$\ell_\infty^\lambda = \left\{x \in w : \sup_n |\Lambda_n(x)| < \infty\right\},$$

$$c^\lambda = \left\{x \in w : \lim \Lambda_n(x) \text{ exists}\right\},$$

$$c_0^{\lambda} = \left\{ x \in w : \lim_{n \to \infty} \Lambda_n(x) = 0 \right\}$$

where $\Lambda_n(x) = \frac{1}{\lambda_n} \sum_{k=1}^{n} (\lambda_n - \lambda_{n-1}) x_k \ (k \in N)$.

H. Ganie and N. A. Sheikh [2] was introduced the spaces $c_0(\Delta_u^{\lambda})$ and $c(\Delta_u^{\lambda})$ as follows:

$$c(\Delta_u^{\lambda}) = \left\{ x \in w : \lim_{n} \hat{\Lambda}_n(x) \text{ exists} \right\},$$

$$c_0(\Delta_u^{\lambda}) = \left\{ x \in w : \lim_{n} \hat{\Lambda}_n(x) = 0 \right\}$$

where $u = (u_k)$ is a sequence of complex numbers such that $u_k \neq 0$ for all $k \in N$ and

$$\hat{\Lambda}_n(x) = \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) u_k (x_k - x_{k-1}) \quad (k \in N).$$

2.Main results

Let $u = (u_k)$ be a sequence of complex numbers such that $u_k \neq 0$ for all $k \in N$. Then we introduce the sequence space

$$\ell_{\infty}(\Delta_u^{\lambda}) = \left\{ x = (x_k) \in w : \sup_{n} \left| \hat{\Lambda}(x) \right| < \infty \right\}$$

where $\hat{\Lambda}_n(x) = \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) u_k (x_k - x_{k-1}) \quad (k \in N).$ (2.1)

If $u_k = 1$ for all $k \in N$, $\ell_{\infty}(\Delta_u^{\lambda})$ reduces to $\ell_{\infty}(\Delta^{\lambda})$ as follow:

$$\ell_{\infty}\left(\Delta^{\lambda}\right) = \{ x \in w : \sup_{n} \left| \overline{\Lambda}_n(x) \right| < \infty \}$$

where $\overline{\Lambda}_n(x) = \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1})(x_k - x_{k-1})$.

Furthe rmore we define the sequence space as follow:

$$\ell_{\infty}^{\lambda,u} = \{ x \in w : \sup_{n} \left| \breve{\Lambda}_n(x) \right| < \infty \}$$

where $\breve{\Lambda}_n(x) = \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) u_k x_k$.

Here and in sequel, we shall use the convention that any term with a negative subscript is equal to naught. e.g. $\lambda_{-1} = 0$ and $x_{-1} = 0$.

Let $\lambda = (\lambda_k)_{k=0}^{\infty}$ be a strictly increasing sequence of positive reals tending to infinity, that is

$$0 < \lambda_0 < \lambda_1 < \ldots \text{ and } \lambda_k \to \infty \text{ as } k \to \infty.$$

We define;

$$\hat{\lambda}_{nk}=\begin{cases}\dfrac{(\lambda_k-\lambda_{k-1})-(\lambda_{k+1}-\lambda_k)}{\lambda_n}u_k, & if \quad k<n,\\ \dfrac{(\lambda_n-\lambda_{n-1})}{\lambda_n}u_n, & if \quad k=n,\\ 0, & if \quad k>n.\end{cases}$$

It is clear that the matrix $\hat{\Lambda}=\left(\hat{\lambda}_{nk}\right)$ is a triangle. We shall assume throught the text that the sequences $x=\left(x_k\right)$ and $y=\left(y_k\right)$ are connected by the relation, that is y is $\hat{\Lambda}$ -transform of x, where

$$y_k(\lambda)=\sum_{i=0}^{k-1}\frac{(\lambda_i-\lambda_{i-1})-(\lambda_{i+1}-\lambda_i)}{\lambda_k}u_i x_i+\frac{\lambda_k-\lambda_{k-1}}{\lambda_k}u_k x_k\text{, for } k\in N\text{ .(2.2)}$$

Here and in what follows, the summation running from 0 to $k-1$ is equal to zero when $k=0$. It is clear from (2.1) that the relation (2.2) can be written as follows;

$$y_k(\lambda)=\sum_{i=0}^{k}\left(\frac{\lambda_i-\lambda_{i-1}}{\lambda_k}\right)u_i\left(x_i-x_{i-1}\right)$$

for $k\in N$.

Theorem 2.1: The space $\ell_\infty(\Delta_u^\lambda)$ is a *BK*-space with the norm

$$\left\|x\right\|_{\ell_\infty(\Delta_u^\lambda)}=\left\|\hat{\Lambda}_n(x)\right\|_\infty=\sup_n\left|\hat{\Lambda}_n(x)\right|.$$

Proof: The proof is seen easily, so we omitted.

One can eaisly check that the absolute property does not hold on the space $\ell_\infty(\Delta_u^\lambda)$ that is $\left\|x\right\|_{\ell_\infty(\Delta_u^\lambda)}\neq\left\|\left|x\right|\right\|_{\ell_\infty(\Delta_u^\lambda)}$ where $\left|x\right|=(\left|x_k\right|)$. Thus, the space $\left\|x\right\|_{\ell_\infty(\Delta_u^\lambda)}$ is *BK*-space of non-absolute type.

Theorem 2.2: The sequence space $\ell_\infty(\Delta_u^\lambda)$ is linearly isomorphic to the space ℓ_∞, that is $\ell_\infty(\Delta_u^\lambda)\cong\ell_\infty$

Proof : To prove the theorem we must show the existence of linear bijection operator between $\ell_\infty(\Delta_u^\lambda)$ and ℓ_∞**.** Hence, let define the linear operator with the notation (2.2), from $\ell_\infty(\Delta_u^\lambda)$ to ℓ_∞ by $x\to y(\lambda)=Tx$ .Then $Tx=y(\lambda)=\hat{\Lambda}(x)\in\ell_\infty$ for every $x\in\ell_\infty\left(\Delta_u^\lambda\right)$. Also, the linearity of T is clear. Further, it is trivial that $x=0$ when ever $Tx=0$ and hence T is injective.

Let $y=(y_k)\in\ell_\infty$ and define the sequence $x=\{x(\lambda)\}$ by

$$x_k(\lambda)=\sum_{j=0}^{k}\sum_{i=j-1}^{j}(-1)^{j-i}\frac{\lambda_i}{u_j(\lambda_j-\lambda_{j-1})}y_i \text{ for } k\in N.$$

Then, we obtain that

$$x_k(\lambda)-x_{k-1}(\lambda)=\sum_{i=k-1}^{k}(-1)^{k-i}\frac{\lambda_i}{u_k(\lambda_k-\lambda_{k-1})}y_i\,.$$

Thus, for every $k \in N$, we have by (2.1) that

$$\hat{\Lambda}_n(x) = \frac{1}{\lambda_n}\sum_{k=0}^{n}\sum_{i=k-1}^{k}(-1)^{k-i}\lambda_i y_i = \frac{1}{\lambda_n}\sum_{k=0}^{n}\left(\lambda_k y_k - \lambda_{k-1}y_{k-1}\right) = y_n$$

This shows that $\hat{\Lambda}(x) = y$ and since $y \in \ell_\infty$, we obtain that $\hat{\Lambda}(x) \in \ell_\infty$. Thus we deduce that $x \in \ell_\infty(\Delta_u^\lambda)$ and $Tx = y$. Hence T is surjective.

Further, we have for every $x \in \ell_\infty(\Delta_u^\lambda)$ that

$$\left\|T(x)\right\|_{\ell_\infty} = \left\|\hat{\Lambda}(x)\right\|_{\ell_\infty} = \left\|x\right\|_{\ell_\infty(\Delta_u^\lambda)}$$

Which means that $\ell_\infty(\Delta_u^\lambda)$ and ℓ_∞ are linearly isomorphic.

Theorem 2.3: The space $\ell_\infty^{\lambda,u}$ is a *BK*-space with the norm

$$\left\|x\right\|_{\ell_\infty^{\lambda,u}} = \left\|\breve{\Lambda}_n(x)\right\|_\infty = \sup_n\left|\breve{\Lambda}_n(x)\right|.$$

Proof: The proof is seen easily, so we omitted.

3. The inclusion relations

Theorem 3.1 : The inclusion $c(\Delta_u^\lambda) \subset \ell_\infty(\Delta_u^\lambda)$ strictly hold.

Proof : Let $x \in c\left(\Delta_u^\lambda\right)$. Then $\left(\hat{\Lambda}\left(x\right)\right) \in c$. Further more, since $c \subset \ell_\infty$ we have $\left(\hat{\Lambda}\left(x\right)\right) \in \ell_\infty$. Hence $x \in \ell_\infty\left(\Delta_u^\lambda\right)$. It is clear that the inclusion $c(\Delta_u^\lambda) \subset \ell_\infty(\Delta_u^\lambda)$ hold.To show that the inclusion is strict,consider the sequence $x = (x_k)$ and $x_k - x_{k-1} = (-1)^k \dfrac{(\lambda_k + \lambda_{k-1})}{(\lambda_k - \lambda_{k-1})u_k}$ for all $k \in N$ .Thus we have that

$$\hat{\Lambda}_n(x) = \frac{1}{\lambda_n}\sum_{k=0}^{n}(-1)^k(\lambda_k + \lambda_{k-1}) = (-1)^n$$

for every $n \in N$.

This shows that $\hat{\Lambda}_n(x) \in \ell_\infty$, but $\hat{\Lambda}_n(x) \notin c$. Thus, the sequence x is in $\ell_\infty\left(\Delta_u^\lambda\right)$, but not in $c\left(\Delta_u^\lambda\right)$. Hence, the inclusion $c(\Delta_u^\lambda) \subset \ell_\infty(\Delta_u^\lambda)$ strictly holds. This completes the proof.

Theorem 3.2 : Theinclusion $\ell_\infty^\lambda \subset \ell_\infty(\Delta^\lambda)$ holds.

Proof: Let $x \in \ell_\infty^\lambda$. Then we deduce that

$$\left|\frac{1}{\lambda_n}\sum_{k=0}^{n}(\lambda_k - \lambda_{k-1})\Delta x_k\right| \le \left|\frac{1}{\lambda_n}\sum_{k=0}^{n}(\lambda_k - \lambda_{k-1})x_k\right| + \left|\frac{1}{\lambda_n}\sum_{k=0}^{n}(\lambda_k - \lambda_{k-1})x_{k-1}\right|.$$

Hence $x \in \ell_\infty\left(\Delta^\lambda\right)$.

Theorem 3.3 : The inclusion $\ell_\infty(\Delta) \subset \ell_\infty(\Delta^\lambda)$ holds.

Proof : Let $x \in \ell_\infty\left(\Delta\right)$.Hencewededucethat

$$\left|\frac{1}{\lambda_n}\sum_{k=0}^{n}(\lambda_k - \lambda_{k-1})\Delta x_k\right| \le \frac{1}{\lambda_n}\sup\left|\Delta x_k\right|\sum^{n}(\lambda_k - \lambda_{k-1}) = \sup\left|\Delta x_k\right|.$$

Therefore, we derive $x \in \ell_\infty(\Delta^\lambda)$.

Theorem 3.4 : The inclusion $\ell_\infty \subset \ell_\infty(\Delta^\lambda)$ strictly holds.

Proof: The inclusion $\ell_\infty \subset \ell_\infty^\lambda$ holds [see 5]. We derived fromTheorem 3.2 that $\ell_\infty^\lambda \subset \ell_\infty(\Delta^\lambda)$. Hence $\ell_\infty \subset \ell_\infty(\Delta^\lambda)$.Further, consider the sequence $y = (y_k)$ defined by

$$y_k = \sqrt{k+1}\,; \quad (k \in N).$$

Then, it is trivial that $y \notin \ell_\infty$. On the other hand, we have that $y_k \in \ell_\infty(\Delta^\lambda)$ from in equality;

$$\sup_n \left| \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) \Delta y_k \right| \le \sup_k |\Delta y_k| \sup_n \left| \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) \right|.$$

$$\le 1$$

Thus, the sequence y is in $\ell_\infty(\Delta^\lambda)$ but not in ℓ_∞. We therefore deduce that the inclusion $\ell_\infty \subset \ell_\infty(\Delta^\lambda)$ is strict. This concludes the proof.

Theorem 3.5:

i.For $|u_k| \le 1$ for all $k \in N$, the inclusion $\ell_\infty(\Delta^\lambda) \subseteq \ell_\infty(\Delta_u^\lambda)$ holds.

ii. For $|u_k| > 1$ for all $k \in N$, the inclusion $\ell_\infty(\Delta_u^\lambda) \subseteq \ell_\infty(\Delta^\lambda)$ holds.

Proof: (i) Let $x \in \ell_\infty(\Delta^\lambda)$. Then

$$\left| \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) \Delta x_k \right| < \infty.$$

Since

$$\left| \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) u_k \Delta x_k \right| \le \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) |u_k| |\Delta x_k|$$

$$\le \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) |\Delta x_k| < \infty,$$

We have $\ell_\infty(\Delta^\lambda) \subseteq \ell_\infty(\Delta_u^\lambda)$.

(ii) Let $x \in \ell_\infty(\Delta_u^\lambda)$. From in equality

$$\frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) |\Delta x_k| \le \frac{1}{\lambda_n} \sum_{k=0}^{n} (\lambda_k - \lambda_{k-1}) |u_k| |\Delta x_k| < \infty,$$

We have that $\ell_\infty(\Delta_u^\lambda) \subseteq \ell_\infty(\Delta^\lambda)$.

Theorem 3.6 :

i.For $|u_k| \le 1$ for all $k \in N$, the inclusion $\ell_\infty^\lambda \subseteq \ell_\infty^{\lambda,u}$ holds.

ii. For $|u_k| > 1$ for all $k \in N$, the inclusion $\ell_\infty^{\lambda,u} \subseteq \ell_\infty^\lambda$ holds.

Proof : (i) Let $x \in \ell_\infty^\lambda$. Then

$$\frac{1}{\lambda_n}\sum_{k=0}^{n}(\lambda_k - \lambda_{k-1})|u_k||x_k| \leq \frac{1}{\lambda_n}\sum_{k=0}^{n}(\lambda_k - \lambda_{k-1})|x_k| < \infty .$$

We have $\ell_\infty^\lambda \subseteq \ell_\infty^{\lambda,u}$.

(ii) Let $x \in \ell_\infty^{\lambda,u}$. Then we derive that

$$\frac{1}{\lambda_n}\sum_{k=0}^{n}(\lambda_k - \lambda_{k-1})|x_k| \leq \frac{1}{\lambda_n}\sum_{k=0}^{n}(\lambda_k - \lambda_{k-1})|u_k||x_k| < \infty .$$

Hence $\ell_\infty^{\lambda,u} \subseteq \ell_\infty^\lambda$.

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Mild Steel Corrosion in Different Oil Types

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ABSTRACT

This research was undertaken to examine possible corrosion in petroleum pipelines by determining the corrosion kinetics of mild steel in a number of petroleum and biodiesel oil types. Weight loss measurements carried out for 25 days (at 5 days interval) showed corrosion rate was highest in Premium Motor Spirit (PMS) amongst petroleum refined products, followed in descending order by Dual Purpose Kerosene (DPK) and Automotive Gas Oil (AGO). Amongst 100% by volume biodiesels, coconut oil impacted more corrosion on mild steel, followed in descending order by olive oil and vegetable oil. Lastly, high corrosion rate was experienced in Russian crude oil (Urals) compared to its negligibility in Nigerian crude oil (Escravos). Among biodiesels and petroleum fractions, it has been observed that corrosion rate increases with decrease in density and increase in weight percent of hydrogen in the hydrocarbon media. High sulfur content has been found to account for the high corrosiveness of Russian crude oil.

Keywords: Corrosion, mild steel, petroleum, biodiesel, weight loss method.

1. Introduction

Material selection is a very critical component of every manufacturing company. Keen considerations are therefore given to industrial designs of materials to ensure maximum efficiency and effectiveness from their usage (Ukoba *et al*, 2012). Mild steel is an important engineering material which serves a wide range of industrial applications. It is used amongst others in petroleum production and refining, marine applications, petrochemicals and polymer production and synthesis, construction equipment, chemical processing, mining and transmission pipelines.

Mild steel is largely amongst the most common materials used for petroleum pipelines due to its distinct physical characteristics which include ductility, enormous strength, weldability, and its amenability to heat treatment for various mechanical properties (Smith & Hashemi, 2006; Bolton, 1994; Davies & Oelmann, 1983). Because the use of mild steel as a petroleum transmission pipeline is subject to a number of factors such as content of the petroleum product passing through it, the temperature and pressure of the contents, mild steel is often fabricated in such ways that it could suit the stringent needs and services desired (Badmos *et al*, 2009).

Corrosion, undoubtedly one of the most destructive agents and probably the greatest consumer of metal known to man, is one of the major causes of pipeline defects around the world (Ukoba *et al*, 2012; Callister, 1997). Mild steel therefore corrodes quite easily due to the ability of all common structural metals to form surface oxide films when exposed to pure air; but the oxide formed on mild steel is readily broken down, and it is not repaired in the presence of moisture (Hassan, 2013). Mild steel (Fe) undergoes a spontaneous reaction with air (O_2) and moisture (H_2O) to form an often insoluble and usually non-protective reddish brown hydrated ferric oxide known as brown rust (Badmos *et al*, 2009). This complex process is simplified by the chemical equation shown below:

$$4Fe(s) + 2H_2O(l) + 3O_2(g) \rightarrow 2Fe_2O_3.H_2O(s) \qquad (1)$$

This study determines possible corrosion in petroleum pipelines and its underlying causes with respect to the media, by examining the corrosion behavior of mild steel in different petroleum and biodiesel oil types which include Nigerian and Russian crude oils; refined Nigerian petroleum products- Premium Motor Spirit (PMS), Dual Purpose Kerosene (DPK) and Automotive Gas Oil (AGO); and 100% by volume biodiesels (B100) of vegetable oil, olive oil, and coconut oil. The study is aimed at finding the extent to which the various hydrocarbons corrode pipelines so as to assist in design and selection of materials for qualities which would prevent corrosion.

2. Experimental

2.1 Materials

PMS (Warri refinery), DPK (Kaduna refinery), and AGO (Old Port Harcourt refinery) were procured from the NNPC Yola depot. Nigerian (Escravos) and Russian (Urals) crude oils were obtained from the Kaduna refinery. Synthesized Olive oil B100, vegetable oil B100, and coconut oil B100 were procured from the American University of Nigeria (AUN) organic chemistry laboratory. Analytical grade acetone & ethanol reagents were also used. Sheets of mild steel metal of thickness 0.18 cm were obtained from, and mechanically cut into coupons, 5x2.2 cm, at the metal market along Jimeta bye-pass.

2.2 Methods

The mild steel coupons were first of all polished with sand paper, and cleaned with tissue paper and clean cloth. They were washed first with tap water, then distilled water, and finally washed with acetone in order to degrease them. The specimens were then completely air dried, and weighed on an analytical balance to four decimal places. They were then dipped completely into beakers (250 mL) containing 200 mL each of Nigerian crude oil, Russian crude oil, PMS, AGO, DPK, olive oil B100, vegetable oil B100, and coconut oil B100. After every 5 days (up to 25 days), the specimens were removed from the oil products and cleaned with tissue paper and fine cloth. They were then washed with ethanol, and cleaned again with tissue paper and fine cloth to remove traces of oil. They were afterwards washed again with distilled water, further washed with acetone, and dried in air. Finally their weights were recorded, and the differences in weights at each interval and the rates of weight losses (corrosion rates) were all determined.

$$Corrosion\ Penetration\ Rate = 87.6\ W/DAT \qquad (2)$$

where W is the weight loss in mg, D is the metal density in g/cm^3, A is the area of the sample in cm^2 and T is the time of exposure of the metal sample in hours.

3. Results and Discussion

Table 1 provides the density values for the various liquid products or media used for the study. It could be deduced that among the petroleum fractions (that is refined products), density increases from PMS to DPK and AGO. The biodiesels on the other hand fall within the range of the density of AGO.

Uniform corrosion was observed in the test coupons immersed in the different oil media, and results for the weight loss measurements are shown in Table 2. The respective plot diagrams of weight loss in petroleum oil types, biodiesels and Russian crude oil, and corrosion rate in all oil types are shown in Figures 1 to 4. The data reveals that coconut oil B100 shows the highest amount of weight loss among the biodiesel oil types, followed by olive oil, then vegetable oil. And among the refined petroleum products, highest corrosion rate and weight loss are observed in PMS, followed in descending order by DPK and AGO. Lastly, Russian crude oil shows a tremendous amount of corrosion compared to its Nigeria counterpart, in which zero weight loss has been observed.

The observed differences among the two classes of oil (refined petroleum products and biodiesels) could be attributed to the differences in their densities. It has been deduced that corrosion tends to increase (that is while comparing each class separately) as density decreases. This decrease in density accounting for increase in weight loss and corrosion rate is as a result of increase in the weight percent of hydrogen content in the media (Badmos *et al*, 2008; Hassan, 2013). Russian crude oil is observed to have impacted a very high corrosion on mild steel. This is as a result of the high amounts of sulfur in the crude oil, making it a perfect example of sour oil (Farahbod *et al*, 2014). Nigerian crude has proven its international oil market desirability as a sweet oil, impacting no or negligible corrosion on the mild steel.

4. Conclusions

Corrosion rate among biodiesels and petroleum refined products tends to increase with decreasing density and increasing weight percent of hydrogen in the hydrocarbon media. Corrosion rate for biodiesels is highest in coconut oil B100, followed in decreasing order by olive oil B100 and vegetable oil B100; while for refined petroleum products it is highest in PMS and followed in that order by DPK and AGO. It has been observed that corrosion is tremendously high in Russian crude oil compared to its negligibility in Nigerian crude oil. This contrasting effect owes to the high sulfur content of Russian crude (a sour crude oil) and low sulfur content of its Nigerian counterpart (a sweet crude oil).

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Table 1. Densities of the petroleum and biodiesel products

	Olv./oil B100	Veg./oil B100	Coco./oil B100	PMS	DPK	AGO
Density (kgm^{-3})	855.14	861.11	842.40	733.34	823.30	875.60

Table 2. Weight loss of mild steel in the different oil types

	Weight loss ($mg\ cm^{-2}$)				
Oil types	**5 days**	**10 days**	**15 days**	**20 days**	**25 days**
Olive oil B100	0.0512	0.0767	0.0853	0.1364	0.3325
Vegetable oil B100	0.0201	0.0402	0.0503	0.1307	0.2011
Coconut oil B100	0.1909	0.3545	0.4455	0.4636	0.5000
PMS	0.0279	0.0465	0.0651	0.1023	0.2419
DPK	0.0085	0.0340	0.0510	0.0765	0.2041
AGO	-	0.0097	0.0100	0.0484	0.1938
Nigerian crude oil	-	-	-	-	-
Russian crude oil	0.0089	0.0622	4.1244	6.5067	9.6356

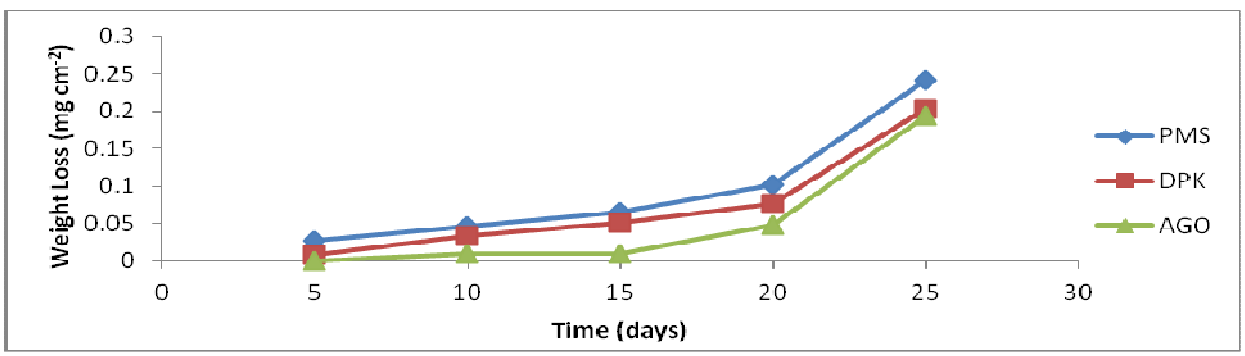

Figure 1. Weight Loss of mild steel in petroleum fractions

"We'd have our place where we belonged": Steinbeck's *Of Mice and Men* and the Quest for a Lost Eden

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Abstract

*This is a paper that looks into Steinbeck's novella **Of Mice and men** examining the dreamers' vision of a life that gets them out of their miserable existence as poor workers. Its aim is to examine the reasons of the failure of the dream which the protagonists attempt to transform into reality. This is done by analysing such characters in terms of their capacities as questers, and the type of life they aspire to get in the light of its validity or relevance to their present status as workers or labourers.*

"We'd have our place where we belonged": Steinbeck's *Of Mice and Men* and the Quest for a Lost Eden

The idea of quest is originally a religious one, drawing on the Bible. John Steinbeck (1902-1968), the well-known twentieth-century American novelist, draws constantly, in his prose, on the Bible, folklore, the Arthurian tales, and Walt Whitman, to name but few obvious sources.[1]

Steinbeck's protagonists are characteristically on the move, as they are migrants workers, labourers, and so on. Throughout their journeys across the country in search of job, home, or a better life, they meet different types of people, and the events that take place are conditioned by either the nature of plans these figures have already set up or by the hazards they must go through with the view to realizing their goals. Yet, Frohock, in studying Steinbeck's works, asserts that Steinbeck is not merely interested in the picaresque form of novel; the novelist, here, goes so far as to reinvent it in such a way as to let his characters, while living by their wits, unconcerned with the moral codes and thus are capable of both "brutality and tenderness."[2] These are picaroons who may or may not possess the moral sense of their traditional peers, and their destination, although reached at the end, will never be a satisfactory resolution of their trouble.

Like the characters of Hemingway, Fitzgerald, and other contemporary novelists, Steinbeck's heroes are basically dreamers. Warren French, in his study of Steinbeck, seems to argue that dreamers in Steinbeck are always doomed due to the failure of nature to grant man the sort of life of which he has been dreaming. Accordingly, the heroes of ***Of Mice and Men*** (1937) and ***The Pearl*** (1947) choose, though unwillingly, to destroy or end their own dreams, as they evidently prove no longer valid, sustainable, or realizable.[3]

However, this sense of predestination or determinism that holds in more than literary work of the period does not necessarily find expression in Steinbeck's other masterpiece ***The Grapes of Wrath*** (1939), where the author apparently seems to challenge the conception of human race's destiny in an indifferent universe.[4] Steinbeck's novels of the thirties, including, ***Tortilla Flat*** (1935) and ***In Dubious Battle*** (1936), are deeply rooted in the contemporary social chaos of the Great Depression.[5] Violent action is, in a way, meant for humanitarian purposes or at least justified, as Frohock tends to suggest, as long as those who are involved in a quest for social justice are denied their natural rights.[6]

The quest for power and glory that ends with a sweeping success is echoed in Steinbeck's first novel ***Cup of Gold*** (1929). Although a work of an immature writer, it has its illuminating aspects and cathartic values showing that Steinbeck probably tried to rid himself, through the pages

describing the life of the buccaneer Henry Morgan, of "the values of his time which he inherited but did not actually accept."[7]

In ***Of Mice and Men***, George Milton and Lennie Small spend most of their time dreaming of having a farm of their own. Having found their job through an employment company, George and Lennie have come to work in a ranch where they meet Candy, an old disabled swamper; the boss; his arrogant son; Curley; Curley's wife; Slim, the muleskinner; Carlson; and Crooks, the black stable hand. The story is set on large California ranches during the Depression, a period in which men had to go from one ranch to ranch to find work. The major conflict in the story evolves mainly from the antagonism of the migrants' difficult conditions and other external forces. Carrying their own possessions, "bindles," with them, they are, for the most part, helpless, for they can lose their low-paid jobs so easily. They are lonely, having no families. Nevertheless, their fate is decided yet by another factor. Accordingly, conflict is encountered when some personal defects play no less significant role than that of those forces.

In an essay on ***Of Mice and Men***, critic C. C. Hadella refers to a significant issue that other critics have already noted. Since the Garden of Eden myth is clearly alluded to in the novel, Steinbeck appropriates Edenic elements to convey his personal interpretation of the American Dream. The role of woman in the Edenic framework is that of the temptress, the despoiler of the Garden. Therefore, the mythical discourse of the fiction dictates that a woman precipitates the exile from Paradise [8] In the novel, Curley's wife plays this role of the seductive "tart" that will provide the catalyst for the later tragic events,[9] resulting in not only her and Lennie's destruction, but also the obliteration of the very basis on which George's and Lennie's dream has been founded.

To realize a dream, the author argues, there must be a friendship of a special kind. Those friendships made are either temporary or ordinary. The mentally retarded Lennie must depend or rely on the comparatively self-sufficient George, who is the more intelligent, mature and inexperienced in managing the farm. Without this friendship, neither of them could practically sustain the dream. With this friendship, the dream becomes a possibility. Steinbeck uses dramatic irony to suggest the remoteness of the possibility of fulfilling the dream. Though there are obstacles, there is still a chance of achieving it with the intelligent George and the physically powerful Lennie. In the end, both men and their dream are defeated by circumstances or by chance. The handicapped in the migrant world are doomed or fated.[10]

The river bank and the ranch provide, on one level, the idyllic and real boundaries of the two guys' imaginary, utopian world. The centrally placed bunk house and barn, offering only physical security and a minimum of that, symbolize the essential emptiness and impersonality of that world. The fundamental symbol which keeps the two men together, stimulates hope for two others (Candy and Crooks), and very likely expresses the hopes of still others, is the dream in itself[11]: "a little house and a couple of acres an' a cow and some pigs ..."[12] The impossibility of dream, however, is articulated in Crooks' pessimistic but truthful and realistic viewpoint:

I seen hundreds of men come by on the road an' on the ranches, with their bindles on their back an' that same damn thing in their heads. .... They come, an' they quit an' go on; an' every damn one of 'em's got a little piece of land in his head. An' never a God damn one of 'em ever gets it. Just like heaven. Ever' body wants a little piece of lan'.... Nobody never gets to heaven, and nobody gets no land. It's just in their head. They're all the time talkin' about it, but it's jus' in their head." (p. 74)

Yet, the first thing that undermines the quest and puts an end to the dream of restoring the lost Eden, as Watt suggests, lies in the very incongruity of the questing pair. George is alert and shrewd; rough, contemptuous and callous in manner; Lennie, pathetically eager to please, imitating his friend, barely able to think or remember the simplest things[13] It is strange for Slim to see such a "cuckoo like him [Lennie] and a smart little guy [George] ... travelin' together" (p. 39). Bodily strong but mentally feeble, as he is, Lennie is, after all, a "nice fella" (p. 40). George declares to Slim that he (George) is used to Lennie, and is ready to reiterate the soothing "ritual phrases invoking the

peaceful promised land"[14] for him over and over. The recurrent description of the dream vision of "a house and a couple of acres" is a "set speech, without strong conviction, demonstrating George's understanding of the unlikelihood of the dream but also of its necessity to both inspire and control his companion."[15]

Lennie is, as a matter of fact, as innocent as a child, which relatively removes his responsibility for what he does. Jeffery D. Schultz finds it strange that nothing much is known about this friendship or about George's acceptance of responsibility for a fellow human being to whom he has no blood relationship.[16]

The real problem with Lennie is that he often gets himself and his companion in trouble; he is, like "a big baby," in a compulsive love with petting such nice "soft things" (p. 90) as mice, puppies, rabbits, or a women's dresses or hair. It is Lennie's foolishness or imbecility that has caused his and George's expulsion from their job, as Lennie has been caught feeling the dress of a girl. Therefore, without George's watchful eye, he, while trying to express his infantile reactions, could easily kill what he touches. Thus, he needs George to act like his guardian.[17] Lennie, in Howard Levant's opinion, is "the reduction of humanity to the lowest common denominator."[18] Rather than being an allegorical representation of insanity; Lennie is the "inarticulate and powerful yearnings of all."[19] In like manner, he is a symbol for the animal appetites in man: the craving to touch and feel and the impulse towards immediate gratification of sensual desires.[20]

However, it seems that Lennie's falling in trouble is inevitable, the thing which is anticipated by George in Part One, when he tells Lennie to hide in the brush at the same spot where they are until he (George) comes for him in case he (Lennie) gets in trouble. Furthermore, it is, more or less, foreshadowed by Lennie's petting of a dead mouse in the same part, and his killing of a "puppy" while petting it in Part Four. The climax of the action is when Lennie, unintentionally does "another bad thing" by killing Curley's wife, who is their boss's daughter-in-law, while he has been feeling her hair. Fully aware that "Lennie never done it in meanness" (p. 95), George feels the necessity to act. His final shooting of Lennie to save him from lynching is foreshadowed by the earlier shooting of Candy's useless, stinking sheepdog by Carlson. Levant argues that Lennie dies necessarily because friendship can go no further than it does go, and nothing can be made of the dreamlike idea of the little farm.[21]

Although left free, George ultimately recognizes or senses the utter futility and loneliness of his new life. Although he expresses more than once to Lennie, especially in time of his frustration, that his life without him (Lennie) would be much brighter and easier: "I could get along so easy and so nice if I didn't have you on my tail" (p. 7), he, in putting up with Lennie's foolish and fatal mistakes, "gains" from him "as much as he gives."[22] In accordance with one reading of the novel, Lennie becomes a personification of the division between mind and body. George is motivated to protect Lennie as he realizes that the latter is "the reverse image of his own human nature."[23] With Lennie gone, the possibility of realizing the dream is gone forever.[24]

Yet the very idea of the quest for an Edenic life is in itself defective. It may very likely be a reaction to their hopeless, difficult life, as George, addressing Lennie, declares: "We'd have our own place where we belonged and not sleep in no bunk house" (p. 57). With Candy's remark that the land they are looking can be anywhere: "[it] might be any place" (p. 59), realizing their dream is increasingly becoming possible: "This thing they had they had never believed in was coming true" (p. 60). However, the overemphasis on the perfect quality of the aspired life undermines the very basis for such a life:

> An' we could have a few pigs. I could build a smoke house like the one gran'pa had, an' when we kill a pig we can smoke the bacon and the hams, and make sausage an' all like that. An' when the salmon run up river we could catch a hundred of 'em an' salt 'em down or smoke 'em. We could have them for breakfast …. When the fruit come in we could can it—and tomatoes, they're easy to can. Ever' Sunday we'd kill a chicken or a rabbit. Maybe we'd have a cow or a goat, and the cream is so God damn thick you got to cut it with a knife and take it out with a spoon. (p. 57)

The violent incidents of Curley's punching of Lennie without mercy and the subsequent Lennie's grabbing and crushing of Curley's hand suggest that "Curley's sadistic vision of the world will not be shut out by the idealized vision of the cooperative friends"[25] The too much idealized, simple life envisioned by Lennie and George where "[a]in't gonna be no more trouble. Nobody gonna hurt nobody nor steal from 'em" (p. 106) is by no means compatible with the reality of the dreamers as drifters, first, and with that of America's economic failure during the years of Depression, second. Thus, with the plan excessively idealized, the probability is that life, even if they obtained the farm, "would not consist of the comfort, plenty, and inter-personal harmony they envision."[26]

One reading of ***Of Mice and Men*** the novel gives rise to approaching it as a parable, having the form and characters appropriately. Despite the fact that loneliness is a recurrent theme in the novel, many of Steinbeck's characters are, more or less, personified types rather than realized persons.[27] The writer intends the novel, as he himself puts it, to be a microcosmic "study of the dreams and pleasures of everyone in the world."[28] The wanderings of George and Lennie implies that they are just two men of many who have engaged in a hard search and have camped at the place on the river.[29]

Similarly, Old Candy, helpless to stop the shooting of his dog, knows very well that he too will be banished when he is no longer useful. Nevertheless, he, with his saved money and his eagerness to buy a share in George's and Lennie's dream, is, at least, a moral drive for both to go on in their hard life. Crooks, as a result of his skin colour, lives in isolation and exclusion. Curley's unnamed wife wanders around the ranch in a "wistful quest" for some kind of human contact.[30] Her dream, which predicts her abortive quest, is to be merely in pictures - to become a Hollywood cinematic image that occupies no space in the real world. She is so unfortunate that she is doomed to destruction at the hands of Lennie simply because she is just another soft, furry thing.[31]

Critic David K. Matthews states that Steinbeck's stereotyped characters signify his general concern with the migratory workers. The use of those type characters who are allowed no originality, Matthews goes on to argue, is appropriate to the author's deterministic theme,[32] which is shown in the contrast between the contrasting images of nature in the first and last chapters of the book.

In the opening chapter of Steinbeck's novel, nature looks quite, calm, full of life, energetic, and peaceful, as if in harmony with the man's hope for a better future and his ambition to attain the desired life he feels that it must be somewhere in this world. Here is how nature initially looks like in this context:

> … but on the valley side the water is lined with trees— willows fresh and green with every spring, carrying in their lower leaf junctures the debris of the winter's flooding; and sycamores with mottled, white, recumbent limbs and branches that arch over the pool. On the sandy bank under the trees the leaves lie deep and so crisp that a lizard makes a great skittering if he runs among them. Rabbits come out of the brush to sit on the sand in the evening, and the damp flats are covered with the night tracks of 'coons, and with the spreadpads of dogs from the ranches, and with the split-wedge tracks of deer that come to drink in the dark. (p. 1)

Here, the possibility of realizing the lost paradise is, though practically seems unlikely, remains, after all, existent, This is, for Lennie and George, the best place to set out their quest for finding out their lost happiness and establishing their new life upon reaching their final destination.

However, when things, later on, turn to have a new course or direction that is entirely at odds with what the two guys have earlier planned, the same nature that is witnessed in the very first scene of this play-novelette, seems utterly different. It is, presently, tainted with an image associated with evil, or something that signals the disturbance of the former natural peace and, consequently and symbolically, the falling apart of the dream altogether:

> The deep green pool of the Salinas River was still in the late afternoon. Already the sun had left the valley to go climbing up the slopes of the Gabilan Mountains, and the hilltops were rosy in the sun. But by the pool among the mottled sycamores, a pleasant shade had fallen. A

> water snake glided smoothly up the pool, twisting its periscope head from side to side; and it swam the length of the pool and came to the legs of a motionless heron that stood in the shallows. A silent head and beak lanced down and plucked it out by the head, and the beak swallowed the little snake while its tail waved frantically. (p. 99)

The wildlife and vegetation, as Matthews emphasizes, are so equally described both times that the impression given is that of timelessness; time has not actually progressed at all.[33] The same setting in which the novella begins and ends suggests a "never ending circle to human endeavour."[34] It is actually more than a little spot by the river where the two meet; coming to it symbolizes a retreat from the world to a primeval innocence.[35]

The shooting of Lennie, as well as the earlier death of Curley's wife, carries with it the end of the labourers' dream of owning land.[36]

Another reason why the sought Eden is irretrievably lost is the power of fate characters. Indeed, George "cannot control fate, any more than he could control Lennie. What he can control is the manner of Lennie's death."[37] Peter Lisca believes that this slight power of the protagonists' free will is the thing through which the author achieves balance with the fore of circumstances.[38]

Viewed in the light of its mythic and allegorical implications, the novel is the story about the nature of man's fate in a fallen world. With the farm as an image or metaphor for heaven, the failure to achieve the dream farm is most likely associated with the question of man's failure to attain heaven. The story suggests the futility of human attempt to recapture Eden, although the characters dedicate themselves to the elusive grail of fellowship.[39] Lisca summarizes the pointlessness of the dream itself since there are only illusions of Edens in Steinbeck's writing. Moreover, "in the fallen world of the Salinas Valley the Promised Land is an illusory and painful dream."[40]

Conclusion

Of Mice and Men is one of Steinbeck's novels that end with a tragic note of pessimism. Though the characters have kept a positive drive towards alleviating their harsh life conditions with the help of a microcosmic idealistic vision of how their life on their own small piece of land or farm will be, they never reap any fruits in the end. They come to discover that their reality as helpless drifting workers never matches with the essence of their dreams as landowners or with the quality of life they do seek.

George and the other co-workers are practical in the sense that their feeling of dissatisfaction with their life yields or results in not only a dream of change but also in their strong impulse or enthusiasm for action. What they fail to realize is the futility of looking for an Edenic existence in an evil environment, and the inevitability of the defeat of any plan set for the realization of such a dream.

Notes

[1] Jane Benardete, ed., ***American Realism: A Shape for Fiction*** (New York: Capricorn books, 1972), p. 385.

[2] W. M. Frohock***, The Novel of Violence in America*** (Dallas: Southern Methodist University Press, 1957), pp. 125-126.

[3] Warren French, ***John Steinbeck's Fiction Revisited*** (New York: Twayne Publishers, 1994), p. 32.

[4] Ibid, p. 39.

[5] F. W. Watt, ***John Steinbeck*** (New York: Grove Press, Inc., 1962), p. 51.

[6] Frohock, p. 125.

[7] Maxwell Geismar, ***Writers in Crisis: The American Novel, 1925-1940*** (Boston: Houghton Mifflin Company, 1942), p. 248.
[8] Charlotte Cooke Hadella, "The Dialogic Tension in Steinbeck's Portrait of Curley's wife" in Tetsumaro Hayashi and John H. Timmerman, eds. ***John Steinbeck: The Years of Greatness, 1936-1939*** (Tuscaloosa & London: The University of Alabama Press, 1993), pp. 68-69.

[9] Jeffrey D. Schultz and Luchen Li, ***Critical Companion to John Steinbeck: A Literary Reference to His Life and Work*** (New York: Facts on File, Inc., 2005), p. 146.

[10] Paul McCarthy, ***John Steinbeck*** (New York: Frederick Ungar Publishing Co, 1980), pp. 58-60.
[11] Ibid, p. 62

[12] John Steinbeck, ***Of Mice and Men*** (Penguin Books, 1993), p. 14. All subsequent references to this novel, hereafter cited parenthetically within the text, are to this edition.
[13] Watt, pp. 59-60.

[14] Ibid, p. 62.

[15] Jeffrey D. Schultz and Luchen Li, p. 147.

[16] Ibid, p. 146.

[17] Watt, p. 59.

[18] Howard Levant, ***The Novels of John Steinbeck: A Critical Study*** (Columbia: University of Missouri Press, 1988), p. 134.

[19] Watt, p. 61.

[20] William Goldhurst, “John Steinbeck’s Parable of the Curse of Cain” in Michael J. Meyer, ed., ***The essential Criticism of Jon Steinbeck’s Of Mice and Men*** (Maryland: The Scarecrow Press, Inc., 2009), p. 58.

[21] Levant, p. 140.

[22] Watt, pp. 60-61.

[23] Levant, p. 135.

[24] McCarthy, p. 60.

[25] Levant, p. 142.

[26] Goldhurst, p. 57.

[27] Levant, p. 135.

[28] Watt, p. 61.

[29] David K. Matthews, "Allegory and Determinism in Steinbeck's *Of Mice and Men*" in Robert Stanton, ***An Introduction to Fiction*** (Chicago: Holt, Rinehart, and Winston, Inc., 2006), p. 84.

[30] Anne Loftis, "A Critical Introduction to *Of Mice and Men*" in Jackson J. Benson, ed., ***The Short Novels of John Steinbeck*** (Durban and London: Duke University Press, 1990), p. 42.

[31] Hadella, pp. 70-72.

[32] David K. Matthews, p. 83.

[33] Ibid, p. 83.

[34] Jeffrey D. Schultz and Luchen Li, p. 147.

[35] Peter Lisca, "On Symbols in *Of Mice and Men*" in Harold Bloom, ed., ***John Steinbeck's Of Mice and Men: Bloom's Guides*** (Philadelphia: Chelsea House Publishers, 2006), p. 69.

[36] David K. Matthews, p. 85.

[37] Jeffrey D. Schultz and Luchen Li, p. 147.

[38] Lisca, p. 72.

[39] Goldhurst, pp. 52-60.

[40] Louis Owens, "Of Mice and Men: The Dream of Commitment" in Don Noble, ed., ***Critical Insights: John Steinbeck*** (New Jersey: Salem Press, 2011), p. 145.

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Particle size distribution and its effect on hand drilling technique in the River Benue floodplain, North Eastern Nigeria

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Abstract

The research assessed the suitability of the floodplain alluvial formations for application of the low cost hand drilling techniques along river Benue valley, North Eastern Nigeria.Floodplain sedimentology was assessed from seventeen natural riverbank outcrops and twelve hand-drilled boreholes. At each location, sediment samples were collected from every exposed sedimentological unit. Locations and elevations were determined using a ProMark3 dual frequency GPS instrument.The sediment samples collected were analysed usingCILAS laser diffraction instrument, which characterise particle size distributions between 0.04 and 2,500 µm.The particle size analysis for the sediment samples showed that the samples were largely sandy in nature across the floodplain. This sediment sample can allow easy water flow through the layers for aquifer recharge.These types of alluvial sediment are suitable for application with the hand drilling techniques.

Key words: River Benue, hand drilling technique, floodplain sedimentology, particle size distribution, CILAS instrument.

1 Introduction

Handdrilled wells are suitable for water supply or irrigation purpose and are more affordable than machine-drilled wells.These type of wells are more productive than the hand-dug wells, thereby providing access to improved sustainable water points at a lower cost (Labas et al., 2010; Vuik et al., 2010). Hand drilling is a practical solution for tube wells less than 40 m deep in loose alluvial sediments such as sand, silt and clay and soft weathered rock formations such as soft sandstone and limestone (Labas et al., 2010; Vuik et al., 2010).

The application of handdrilling is limited to areas with soft unconsolidated geological formations such as the alluvial deposits, sufficiently shallow water tables and high permeability aquifers (RWSN, 2012). Many suitable areas of loose sediments, Quaternary alluvial deposits exist along the river Benue floodplain and shallow water table in lowland areas of Yola region. Low-cost handdrilling is commonly practiced by farmers for extracting groundwater along the alluvial floodplain of River Benue for irrigation activities.

The uses of the hand drilling techniques by farmers occur in different drilling fields, all over the world. However, every drilling technology has a special range of conditions where the technique is most effective in dealing with the inherent hydrogeology conditions and in fulfilling the purpose of the intended drilling technique for the specified study location.

2.2 The geological suitability

Geological suitability is related to the hardness of the layers of rock formations (Kane et al., 2013). Hand drilling techniques are only suitable for unconsolidated sediments, but do not allow drilling in hard formations. Sediment formations are suitable for application using hand drilling, especially soft sand, silt and clay. Manual drilling methods are viable only in specific geologic formations (Weight et al., 2013). However, there is currently no available information on geological suitability in the present study even though hand drilling is commonly used. This research has characterised the alluvial floodplain sediment to assess the geological suitability for the manual drilling methods. According to the review above, the geological suitability for manual drilling method is based on the soft unconsolidated alluvial floodplain formations.

2.3 The suitability based on sediment permeability

The permeability characteristic suitable for manual drilled wells is about the possibility to manually drill a small shallow borehole in permeable ground that can yield a significant flow rate (Kane et al., 2013). It is important to understand whether the types of sediment formation been drilled are permeable or impermeable. Permeability is an ability of sediment formations to transmit water through it (RWSN, 2010). Different types of sediment formations encountered during drilling included sand and silt, mixed formations and clay. Table 1 shows the classification of the particle sizes in a alluvial sediment samples.

- Sand and silt formation: It allows easy flow of water through the open space between the sediment particle sizes and thus, very permeable. When drilled through this type of formation, water fills the borehole easily which can be abstracted for irrigation activities or any other use.
- Mixed formations: consists of a mixture of sand, silt and clay. Water flows slowly through the mixed formations and they are described as semi permeable. When drilled through this type of formation, it allows a slow flow of water into the well.
- Clay: clay particles are very sticky and water does not easily flow through its formation and thus, are impermeable. When drilled through this type of formation, it does not allow flow of water into the well and the well will be empty.

Table 1: Classification of the particle sizes in a sediment sample (RWSN, 2010)

SN	Particle name	Particle size (mm)
1	Clay	<0.004
2	silt	0.004 to 0.06
3	Sand	0.06 to 2

Among the criteria discussed above, sand and silt, and mixed formations are more suitable for application for hand drilling techniques, because the formations allow flow of water to recharge a well, which can be easily abstracted for irrigation. Sandy silt formations are very permeable, they allow the flow of the groundwater easily through any open space and are therefore, suitable layers for hand drilling methods.

2.4 The geomorphological suitability

Geomorphological suitability refers to the existence of a surface morphology that facilitates the accumulation of unconsolidated materials, the presence of thick weathered layers and the limited

depth of water. These zones correspond with bottom of the valley and sometimes with flat area with limited slope (Kane et al., 2013).

In general, handdrilling is considered feasible in unconsolidated alluvial formations (sand, silt and clay) with interspersed layers of soft sedimentary rock or laterite (PRACTICA, 2010). General mapping of handdrillingmay be based on analysis of existing data such as local hydrogeological information, interviews and discussion with people. Detailed data regarding existing water points both from existing information as well as direct field observation, topographical maps, well logs, field surveys, geological maps, satellite images and shuttle radar topography information can provide an indication of the potential for hand-drilling in a region (PRACTICA, 2010; Carter et al., 2010).

2.5 Particle size distribution (PSD)

Particle size distribution (PSD) is required to understand the hydrological and structural properties of the sediment samples, which is used to understand the rate of flow through the formation layers. PSD provides a good way of characterising sediments and soils for the purpose of assessment and interpretation (Blott and Pye, 2006; Di Stefano et al., 2010). PSD is useful in the drilling process as coarser sediment sizes allow easy drilling while finer grain size reduce drilling rate. Grain-size parameters of bulk sample have been commonly used as environmental indicators in sedimentary sample investigations (Watson et al., 2013). The PSD forms one of the key parameters of understanding the nature of sediments.

Although no universal model exists to distinguish past depositional environments based on particle size data (McManus, 1988), the PSD of a sediment can provide indications of the energy conditions, transport mechanisms and sorting processes affecting a depositional location (Long et al., 1996).

Floodplains are complex and varied sedimentary environments, where sedimentation is conditioned by a variety of factors, including river flow and topography (Long et al., 1996). Floodplain sedimentary sequences may contain a wide range of particle size, from cohesive clays and silts associated with sands and gravels of channel fills. PSD are therefore a valuable tool in the study of past depositional environments within alluvial floodplain settings, assisting in the identification of both long-term changes related to the evolution of the alluvial floodplain and in the identification of specific sub-environments (Dark and Allen, 2005).

Wide ranges of granulometric techniques are available to the sedimentologist (McManus, 1988). In the study of sediment samples from a floodplain and coastal sequences, instruments using X-ray nephelometry or the scattering of laser or polarised light have largely replaced the older methods based on the pipette, hydrometer or coulter counter (Allen and Thornley, 2004). Laser diffraction requires little time for analysis for a wide size range of samples and requires small size samples (Storti and Balsamo, 2010). The diffraction pattern is used to determine the size of the particle from light scattering method developed by Mie theory (Allen, 1997).

3 Methodology

3.1 Sediments sampling along river Benue Valley outcrops

5,500g of sediment samplefromone hundred and ninety one (191) different sediment sample sites were collected along the outcrops of river Benue valley bank, for the purpose of laboratory analysis. Sampling technique followed the British Standard guideline (BS EN ISO 22475 – 1, 2006). A hand-held Global Positioning System (GPS) was used for fixing the position where sediments were collected in the field. The primary purpose of collecting sediment samples here was for characterisation of the subsurface lithology and stratigraphy of the area (Bob, 2008). At each sampling point, samples were collected at every change of sediment/soil type from the top to the

lithological table/chart was used to describe the samples during sampling. Photographic records with label, scale and colour chart were used for the purpose of description. A small coated plastic (to avoid rust) hand trowel was used for sediment sampling. Samples were put into the sampling bags for laboratory analysis.Samples were also taken in Cameroon in the Benue and Faro rivers (Figure 1) because it contributed sediment to the Nigerian portion of the Benue River.

Field tests for the identification of sediment/soil grain sizes in the field were made by feeling the sediment between fingers. For each sediment collected, a small amount was rubbed between fingers in order to determine the difference between sand, silt and clay. Sand felt gritty, silt felt smooth and clays felt sticky.

3.2 Field sampling ofsediments using hand auger

The visual description of the fresh sediment samples (i.e. their colour) was described according to the Munsell soil colour chart during sampling. Colour patterns of sediment or soil are extremely important for lithological analysis. It is essential to identify the colour of sedimentsduring sampling because some sediments change their colour very quickly in air. An example of this is fine sediment containing iron oxide compounds which, in the fresh-water saturated condition, often has an olive green colour but which rapidly oxidizes to red on exposure to air (BS EN ISO 14688 – 1, 2002). Such kinds of the sediments were the predominant in the floodplain. Colour changes such as those due to oxidation or desiccation were recorded.

Sediment samples were obtained at the drill points in the floodplain for laboratory analysis and to estimate the maximum depth with manual drilling until water was reached during the dry season period.Twelve (12) boreholes were drilled using locally made auger at the twelve points at approximately 500, 1500 and 2500 m intervals along five transects (Figure 4) perpendicular to the river Benue and approximately 500 m between the transects. This seemed a reasonable spacing to cover the area of the Upper Benue Irrigation Project. A total of 4,800g sediment samples in a total number of sixty-five (65) sediment samples were collected from twelve (12) cores for detailed analysis of particle size distribution.

3.3 Particle size analysis

For the present study, CILAS laser diffraction instrument was used, because it was the only available sediment particle analyser in the Institute for the Environment, Brunel University London, UK, for analysing fine sediment. The instrument proved to be good method for analysing the range of grain sizes found in the Yola Benue river floodplain. The CILAS 1180 can characterise particle size distributions between 0.04 and 2,500 μm (Dietmar, 2006). The fine particles were measured by the diffraction pattern using Fraunhofer or Mie theory (CILAS, 2004).Two hundred and fifty six (256) sediment samples were analysed. The results obtained from the CILAS were analysed using Gradistatversion 8.0, a statistical package develop byBlott (2011).

0.05 g of the sediment samples were soaked in 10 ml 10% tetra sodium pyrophosphate, and left over night (12 hours) to deflocculate, before starting measurement. The samples were then added into the CILAS 1180 instrument using the program Size Expert. Care was taken in introducing the amount of sample into the Cilas mixing chamber to avoid high obscuration of sample in the mixing chamber. Since optimal obscuration occurs when a sufficient number of suspended particles are present in the mixing chamber which can significantly diffract the laser beam, but the suspension was not so dense to render the suspension by the laser light. The obscurations for the samples were maintained between 15 to 25% for coarse-grained sediment (Sperazza et al., 2004). Background measurements and rinsing were performed in between each sample measurement in order to keep the results consistent and reliable. Twenty seconds of ultrasound, twenty seconds of pumping and ten seconds of

fast pumping were used for each sample before taking readings. Each sample was run three times for the data consistency and reliability.

The statistical analysis for the alluvial sediment samples was carried out using gradistat software produced by Blott (2011). As suggested by Pye and Blott (2004) statistical parameters can be calculated using the method of moments either arithmetically (based on normal distribution) or geometrically (based on a log normal distribution) that gives a good approximation for well sorted soils and sediments in the present study. The statistical parameters considered were the method of moment's arithmetic. This was because the arithmetic method gave a normal distribution of the floodplain alluvial sediments. The statistical descriptive method (mean, D10, D50, D60, D90, D90/D10, D90-D10, D75/D25, D75-D25, Cu, Skewness and Kurtosis), for sediment samples were used to describe the particle size distribution of the sedimentary deposits, as these parameters describe the key components of a given distribution for the interpretation of the grain size distribution. The particle size distributions were also presented on the surface plot. Surface plots allow a quick overview of the floodplain sediment particle size distribution, so providing useful information on the sediment conditions (Beierle et al., 2002).

4 Result

The sedimentology of the alluvial floodplains, obtained by hand augering along several 2500 m long transects on the left bank of River Benue valley is shown in Figure 3. The studied alluvial sediment deposits ranged between 6 to 18 m in depth at twelve different boreholes before reaching groundwater. The coring always remained in the alluviums overlying sandstone bedrock of the Yola formation but never reached it. The visual logs are presented with measured particle size distribution data (overlying curve) showing distribution of the sediment sizes along the cores at various depths. Visual descriptions of the sediments in field were based on the finger feeling method.

The visual sedimentologyresults showedclayey silt, sandy silt and sand alluvial deposits with sandy silt sediments dominating the alluvial deposit of the floodplain. Clayey silt beds intermixed with sandy silt sediments at different locations and depths (see Figure 3) may serve as local aquitards. The clayey silt on the floodplain would have a significant influence in the aquifer recharge system.

The aquifer in the alluvial floodplainwas made up of fine to medium grained sand with occasional sandy silt. It was observed that borehole location 1 (see Figure 3) closer to the river consists of sand formation and this could be influenced by the river flow. Borehole location 11 at a distance 2,500 m away from the river contained a thick deposition of sand and interfingering with clayey silt and sandy silt deposits. The deposition of sand formation at that location may be likely influenced by the presence of Lake Geriyo grain size range.

The floodplain alluvial sediment colour were mostly light reddish brown with a range between pale red, red, weak red, pale brown, light yellowish brown, gray, and pinkish gray. Only few samples showed olive, olive gray, dark greenish gray, olive yellow, dusty red and pinkish white at various location and depth across the floodplain.

The floodplain grain size was confirmed to be sand, sandy silt and clayey silt by quantitative analysis. Sand and sandy silt samples are dominant across the floodplain having 46% and 52% respectively, and clayey silt samples showing a much lower value of only 2% (Figure 4).

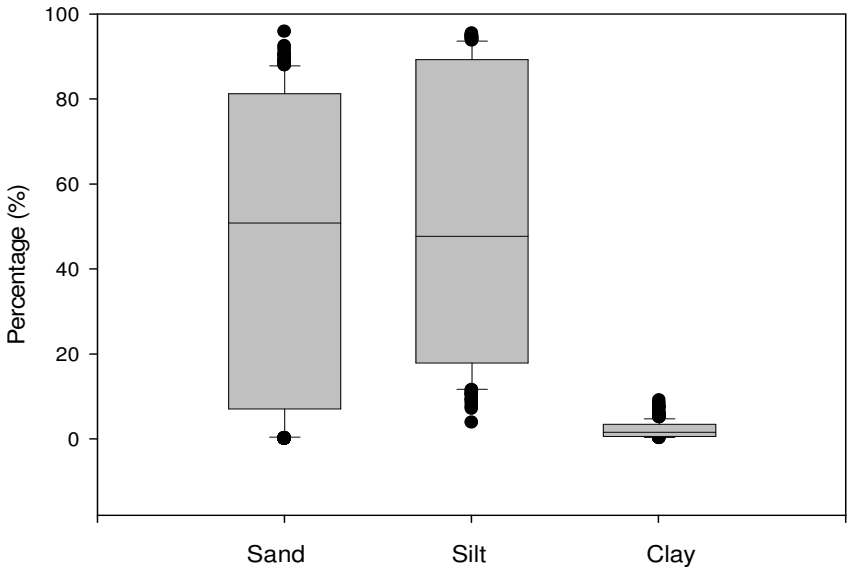

Figure 4: Box plot showing the percentage value range for the sand, silt and clay for the floodplain sediment.

The boxes in Figure 4 represent the median, 25th percentile and the 75th percentile. The whiskers represent 10th and 90th percentiles and the filled circles represent maximum and minimum values.

The particle size distribution (PSD) for borehole cores along the floodplain at different deposition layer sequences was observed (see Figure 5). The interfingering of sandy silt and clayey silt sediments with sand was observed at the depths between 450 to 750 cm and 1050 to 1350 cm respectively in borehole location 11.

Along river Benue outcrop (Figure 6), the interfingering of sand with sandy silt and clayey silt alluvial sediments was observed down the cores. For example, at depths of 225, 345 and 360 cm, the interfingering of sand deposits with sandy silt and clayey silt sediments were observed in outcrop location N.

Figure 7 shows the relationship between percentages of sand with distance away from the river. It can be seen that the distance between 0 to 1000 m away from the river consisted of higher percentage of sand than at a distance 2500 m away from the river. Soil/sediment near to the channel is more likely to be sandy. For example, borehole locations 1, 3 and 9 closer to the river consisted of more sandy sediments (see Figure 3). A weak negative correlation was observed between the percentage sand and distance from the river with the correlation value of -0.268 (p-value of 0.031) (Table 2). This showed that sand sediments decreased away from the river,may be due to different deposition processes because of the high energy environment closer to the river.

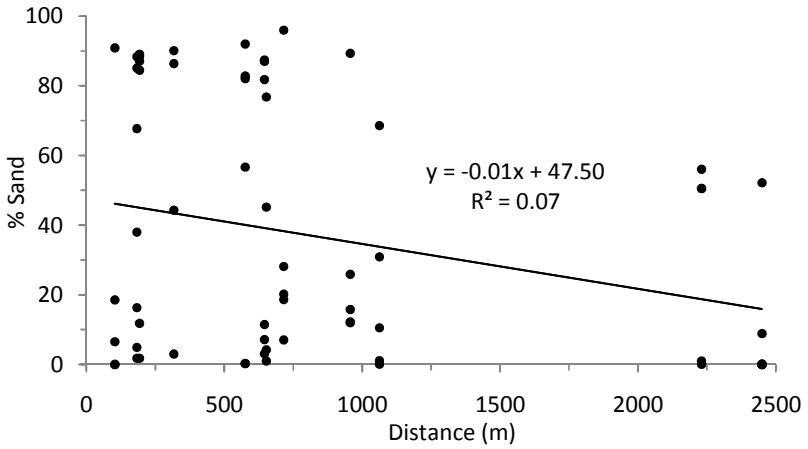

Figure 7: Relationship of sand percentage with distance away from the river.

Table 2: Statistical correlation values and significance range between sand percentages with distance (Significance p-value range 0to 0.05,not significant p-value range 0.06 to 1)

Parameters		% Sand	Distance (m)
% Sand	Correlation	1	
	P-value	0	
Distance (m)	Correlation	**-0.268***	1
	P-value	**0.031**	0

5 Discussion

The river Benue provided an example of braided stream (Miall, 1977), where alluvial deposits are composed of fine-grained sand and sandy silt (see Figure 5). The alluvial sediment of the Benue floodplain consisted of units of sand, sandy silt and clayey silt at various depths in the cores and the outcrops (see Figures 3). The sand-rich deposits may be formed in braided riverbed when sediment influx was high, especially from high flooding events (Brooks, 2003). Braided rivers usually have high flood velocities and material is transported during the peak flow (Miall, 1977). Similar deposition processes was reported by Haschenburger and Cowie (2009) on the braided Ngaruroro river, New Zealand. In that case, lateral migration and formation of coarser-grained layers during large floods were the mechanisms that initiated floodplain development by the braided-rivers.

Distinct coarser sand units with differing sizes were revealed by the coring (see Figures 3 to 6), indicating deposits with different sediment composition possibly from different migration patterns resulting from the river flows. River Benue brings down a large amount of sediment as bed load as

flood events, and very high rainfall events usually in August and September each year, must have had an impact. Parts of these loads were deposited on the floodplain due to very high discharge of the river, giving rise to thick sandy-silt sequences in the plains. Sinha (1995) reported similar deposition on a semi-arid alluvial floodplain in North Bihar, India. Deposition of sand-bed sediment occurred on the floodplain because a high river discharge was observed there.

Marriott (1992) and Walling et al. (1997) reported that river outcrop sediments were consistently coarser, while sediment at a distance from a river are finer. Their findings were contrary to what was observed in the present study, as the alluvial sediment depositions in the core tops vary spatially across the floodplain at different locations and depths (Figures 5). For example,in borehole tops at locations 8 and 11 (Figure 3) away from the river Benue, the majority of the core sampleswere coarse, with some fine sandy silt, which showedflood deposits. The very coarse sediments of core borehole 8 showed the near surface aquifer, while that of borehole 11 are representative of depressions created by Lake Geriyo Basin that occurred between alluvial ridges (for location of Lake Geriyo see Figure 2).

Coarser particles such as sand and sandy silt are permeable formations and therefore transmit water easily. These types of sediments are a common feature of floodplain deposits as defined by Baker (1987). As reported by Grenfell et al. (2009) floodplain sediment are finer while river outcrop sediments are coarser because of the decrease in water energy away from the main flow. However, coarser alluvial sediments vary across the floodplain at different locations and depths (see Figure 3, the floodplain sedimentology).

Hand drilling can only penetrate unconsolidated formations such as sand, sandy silt and clayey silt. The floodplain sedimentology consisted mainly of these types of formations.The floodplain sedimentology showed that the formations are suitable for the application of the low-cost hand drilling technique. This is because the floodplain sediment consisted mainly of sandy silt formations as shown in Figure 3, the visual sedimentology. Similarly, as shown in the river Benue particle size distribution of the outcrop and floodplain sediment (see Figures 4, 5 and 6).

6 Conclusions

Suitability of hand drilling techniques is based on the geological, permeability, and geomorphological requirement. Geological suitability is related to the types of sediment formations. Manual drilling techniques are suitable only on unconsolidated sediment formations such as soft sand, silt and clay. The floodplain sediment consisted mainly of sand and sandy silt formations that are very suitable for application of hand drilling techniques. Suitability based on permeability is related to the types of sediment that allows free flow of water to recharge the floodplain aquifers. Sand and sandy silt formations are dominant across the river Benue floodplain, which are permeable formations and which allow easy flow of water through the formation for recharging the shallow alluvial aquifer. Geomorphological suitability is related to the surface elevation of the floodplain. Low lying surfaces and areas that are relatively flat, as the case in the present study,are suitable for manual drilling. The surface elevations across the floodplain only range between 172 and 178 m (amsl), i.e. a range of 6 m. The floodplain surface elevations are less sloped and therefore suitable for manual drilling to abstract the shallow alluvial aquifers for irrigation and other activities.

Acknowledgements

This study was funded by Petroleum Technology Development Fund (PTDF), Nigerian Government, with additional support from British Geological Survey and Brunel University for the fieldwork surveys.

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Modeling and Simulation of Shinko Drainage Waste water Using *Bacillussubtilis and Pseudomonas aerigunosa* in Jimeta-Yola, Nigeria

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ABSTRACT

The Modeling and Simulation of Shinko Drainage Wastewater Using *Bacillus subtillis and Pseudomonas aerigunosa* was carried out using bioreactor and MATLAB software. A mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa* were formed in the ratio of 1: 1 which was later introduced into some portion of the sample for analysis known as bioaugmented sample. The other sample was collected from Shinko Drainage Wastewater directly known as indigenous sample. The result obtained from the laboratory test was compared to that of mono culture of *Bacillus subtillis*. One hundred percent conversion of the pollutants was achieved for mono culture of *Bacillus subtillis*at approximately 207 days. Regarding, mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*, one hundred percent conversion was obtained at approximately 224 days. Mono culture of *Bacillus subtillis*gives a better result to that of mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*.

KEYWORDS: Bioremediation; *Bacillus subtilis*; *Pseudomonas aerigunosa*; *Simulation*

INTRODUCTION

The high Population growth, poor development plan, chronic unhygienic conditions and lack of proper implementation of environmental laws in Jimeta-Yola, Nigeria leads to pollution of Shinko Drainage wastewater (Sethuraman and Balasubrahamanian, 2010; Mohammed et al., 2010). The wastewater from the drainage is used by animals and for crop production.Due to lack of information on the pollution status of the drainage its continual use could pose a great danger to the consumers of the produce produced using this water and it availability for use which is the usual practice in many part of the word (Luka et al., 2014).

Shinko is situated inJimeta-Yola (Yola-North Local Government Area of Adamawa State in Nigeria) with rapidly growing Populations. The coming up of unplanned houses lead to the proliferation of refuse dumps which unavoidable pose disposal problems and are finally dump into Shinko Drainage channeled into River Benue in Jimeta-Yola, Nigeria (Luka et al.,2014).

Bioremediation of wastewater is currently regarded as the most successful technology for cleanup of pollutants. In bioremediation, organic wastes are detoxified and mineralized under controlled condition into inorganic compounds such as carbon dioxide, water and methane (Basharudin, 2008; Vidali, 2001). Therefore, bioremediation can be defined as any process that uses microorganism, green plant or their enzymes to return the natural environment altered by pollutants to its original conditions (Tarangini,

2009). In bioremediation, the microorganism may be indigenous to a polluted area or may be isolated from other places and introduced to the affected areas to enhance degradation (Vidali, 2001). Biodegradation is one of the processes used to obtain concentrations of chemical substances remaining at a given time either during ex situ or in situ bioremediation. The main focus is always on decrease in pollutant concentration (Okpokwasilli and Nweke, 2005).Organic pollutant can be determined in water using any of the following parametric indicator which are: Dissolved oxygen (DO), Biochemical oxygen demand (BOD), Chemical oxygen demand (COD) and Total organic carbon (TOC) (Tchobanoglous et al., 2003).

Similar research was carried out using mono culture of *Bacillus subtillis* and the results of the investigation shows that bioremediation increases the efficiency of remediation because better results were achieved compared to that of indigenous bacteria (Luka et al., 2014). This study is investigating the efficiency of mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa* in reducing the pollution status of Shinko Drainage wastewater using bioaugmented and indigenous bacteria under aerobic condition.In addition, the result obtained was compared with that of Luka et al. (2014) for mono culture (Bacillus subtillis)bioaugmented and mixed culture (Bacillus subtillisand *Pseudomonas aerigunosa*) bioaugmented for the current Research. The results were modeled and simulated to obtain the level of remediation of pollutants with time.

MATERIALS AND METHODS

Sampling

Sample for analyses were collected from Shinko Drainage located at Shinko area of Jimeta-Yola in Sterilize plastic containers using grab method. The wastewater collected was kept at 4 ℃ inrefrigerator to retard any activity of indigenous bacteria (APHA, 1998).

Isolation of Bacteria

The acclimatized culture of bacteria was isolated using spread plate method. Before inoculating the mixed culture onto nutrient agar; serial dilution was carried out. Original inoculations were diluted in a series of dilution tubes. Five dilution tubes were filled with $0.9\ ml$ of distilled water respectively. Later, 0.1 ml of sample was put into water blank followed by another transferred of $0.1\ ml$of sample from the first dilution into another dilution tube and so on until the dilution of $10^{-5}$was obtained. About$0.01\ ml$ of each dilution was spread evenly over the surface of EMB agar by using a sterilized glass spreader which were incubated at 37 ℃ for a day. The colonies were recorded as colony forming unit per liter (cfu/l). The mixed culture of*Bacillus subtillis*and *Pseudomonas aerigunosa*were formed in the ratio of 1: 1(APHA, 1998).

Bioreactors

Two different bioreactors (1965-00500 M3622129 Belco, USA) of the same capacity were labeled indigenous and bioaugmented respectively. The indigenous sample of the wastewater was first analyzed for chemical oxygen demand (COD) immediately after collection. About $30\ ml$ of inoculums was added

to the sample in bioaugmented reactor and analyzed for COD also. The condition for the reaction in the bioreactor was monitored as stated in Atkinson and Mavituna (1991). The substrate reduction was observed by measuring COD reduction at an interval of three days for twenty sevendays (Luka et al., 2014).

Modeling and Simulation

The ratesand models for bioremediation were obtained using procedure stated in Rawlings and Ekerdt (2002) andLevenspiel (1999). The results obtained were simulated using MATLAB software 7. 12.0(R 2011a).

RESULTS AND DISCUSSION

Theresult obtained by Luka et al. (2014) is represented in Table 1. Table 2 represents the Laboratory analysis for mixed culture of*Bacillus subtillis*and *Pseudomonasaerigunosa*. Order of reaction and their rate constants are presented in Table 3. The graph obtained from the simulation for substrate reduction is presented in Figure 1.

Table 1: Substrate reduction for mono culture of *Bacillus subtillis*

Time(days)	Sm(mg/l)
0	65.35
2	60.33
4	53.76
6	46.2
8	38.9
10	32.12
12	28.9
14	24.87
16	22.65
18	20.42
20	18.9
22	17.23
24	16.58
26	15.59

Sm= Substrate concentration for mono culture

Source: Luka et al. (2014).Kinetics of Bioremediation of Shinko Drainage Wastewater in Jimeta-Yola Using*Bacillus subtillis*, International Journal of Engineering Research and Technology (IJERT) Vol.3 (3), pp 2430

Table 2: Substrate reduction for mixed culture of *Bacillus subtilis*and *Pseudomonasaerigunosa*

Time(days)	Si(mg/l)	Sb(mg/l)
0	62.75	62.75
3	55.8	53.15
6	50.23	47.23
9	44.75	40.19
12	38.44	33.62
15	33.76	28.91
18	30.08	23.21
21	25.12	19.1
24	21.32	16.52
27	20.68	12.98

Si= Substrate concentration for indigenous

Sb= Substrate concentration for mixed culture

Table 3: Order of reaction and rate constant for indigenous, mixed and mono culture

	Rate constant		
Order	Indigenous	*Bacillus subtilis*and *Pseudomonas aerigunosa*	*Bacillus subtillis*
Zero	k_{mi1}= -1.9287	k_{mb1}= -2.2365	k_1= -3.052
First	k_{mi2}= 0.0429	k_{mb2}= 0.063	k_2= 0.069

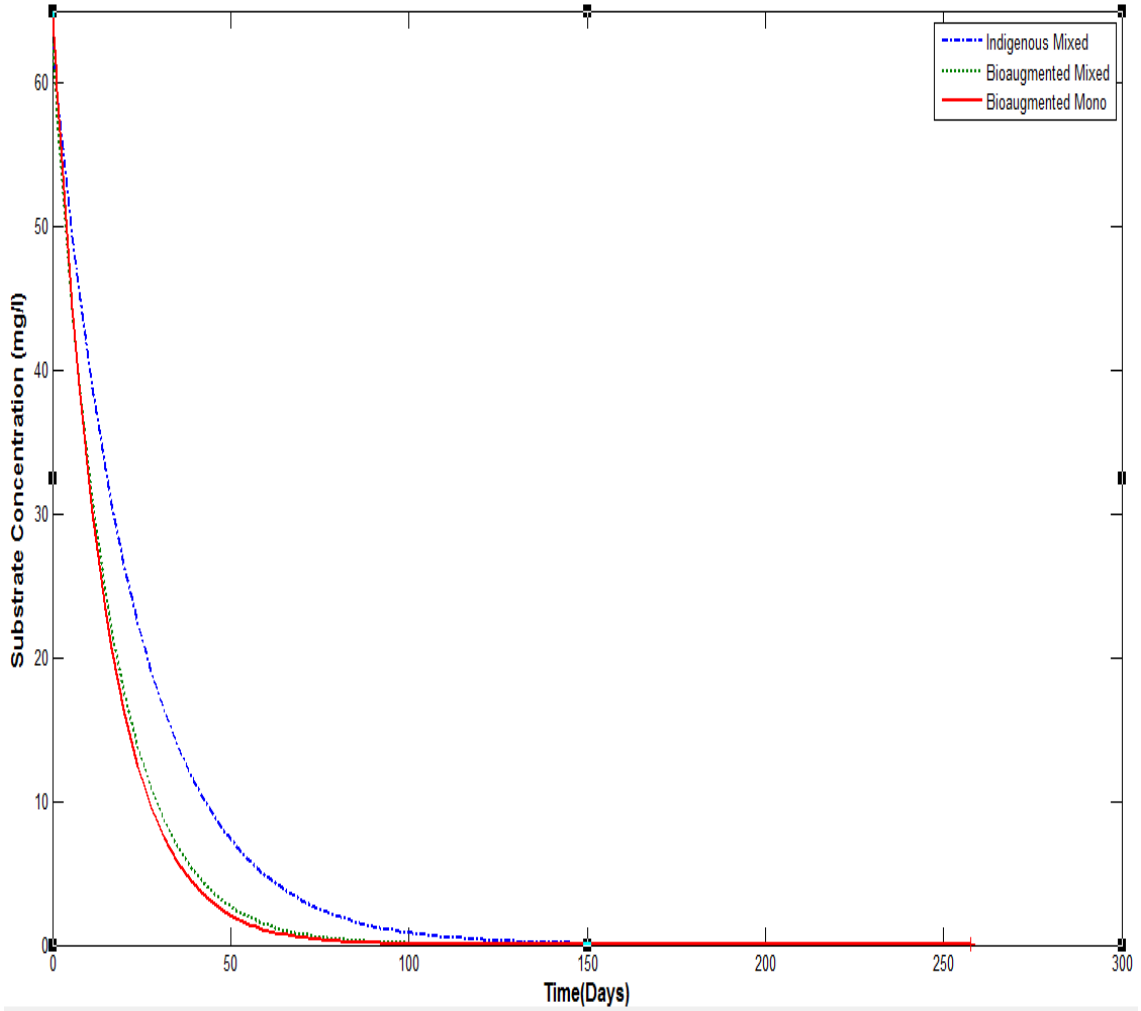

Figure 1: Substrate Reduction by indigenous, mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa* and mono cultureof*Bacillus subtillis.*

Table 1 is extracted from Luka et al. (2014) for the purpose of comparison. This result was simulated together with that of bioremediation using mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*.

Table 2 is the laboratory result obtained for bioremediation using indigenous bacteria and the one using bioaugmented mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*. The laboratory test is carried out for the purpose of obtaining the data to be used for designing a model that will be simulated using MATLAB software. The data needed for the model are the rate constants and the order of reactions. This can be obtained by plotting the rate of utilization of the substrate by bacteria with time. The rate is assumed to be Zero order for early remediation (higher substrate concentration) and first order for late remediation (lower substrate concentration). This type of reaction is referred to as shifting order reaction (Levenspiel, 1999; Monod, 1949).

Figure 1 is obtained from the simulation of the laboratory results using three different bacteria. These include indigenous bacteria used as a controlled sample, mono culture which is a culture where one

bacterium called *bacillus subtillis* is introduced and a mixed culture where two bacteria called *Bacillus subtillis*and *Pseudomonas aerigunosa*are introduced. FromFigure 1, it can be observed that in all cases, the substrate concentration at time (t=0) is very high meaning that the sample of water contain very high substrate before the experiment is being carried out. Upon introduction into the bioreactor, it can be observed that the substrate concentration reduces drastically during the initial days. This can be seen from the steepness of the curve at the point where t=0 and t=50 days. To explain this, it should be understood that the substrate is used as a feed for the bacteria. At the beginning, the substrate concentration is very high and the bacteria have enough substrate to feed on. This will lead to the growth and reproduction of more bacteria which in turn lead to high rate of substrate consumption.

At around 40 days, it can be observed that the substrate concentration has reduced to around 5 mg/l from the initial of over 60 mg/l. this will lead to the death of some bacteria leaving just a few to continue with the bioremediation process. At that point, the curve is observed to bend more towards the right meaning that the rate of substrate utilization has reduced drastically due to the reduction in bacteria.

Comparing the three curves, ie indigenous mixed, bioaugmented mixed and bioaugmented mono cultures, it can be observed that the two curves for bioaugmented mixed and bioaugmented mono cultures are close to each other compared to that of indigenous (control). The two curves have very steep fall compared to indigenous. This shows that the rate of substrate reduction is high for bioaugmented cultures compared to indigenous. The large gap between the bioaugmented cultures compared to that of indigenous indicates that there is large difference between their rates of substrate reduction. This places bioaugmented cultures far above indigenous bacteria in term of substrate remediation.

Comparing the two curves for bioaugmented mono culture and bioaugmented mixed culture, it can be observed that bioaugmented mixed culture is closer to indigenous compared to bioaugmented mono culture. This means that the rate of remediation in bioaugmented mono culture is higher compared to bioaugmented mixed culture. The closeness between the two curves shows that the difference in the rate of remediation is very little.

In the case of bioaugmented cultures, it can be observed from the curves that the substrate concentration is negligible at around 100 days but in case of indigenous bacteria, the substrate concentration is observed to be negligible at around 150 days. This shows that there is advantage of using bioaugmented culture compared to indigenous bacteria in term of the number of days it will take the substrate concentration to be reduced to negligible level. It is also observed that the curves for bioaugmented cultures have aligned with the horizontal at around 200 days meaning that the substrate concentration have been reduced to zero level at the point. For indigenous bacteria, the curve is observed to have aligned with the horizontal at around 250 days which is also the point where the substrate concentration is reduced to zero level.

Inanutshell,Figure 1 show the efficiency of indigenous, mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*as well asmono culture of *Bacillus subtillis* bacteria in remediating the pollutants. The Bioaugmented results for both mono culture of *Bacillus subtillis* and mixed culture of *Bacillus subtillis*and *Pseudomonasaerigunosa* gives better results compared to that of indigenous

bacteria which is in accordance to what was obtained by Luka et al. (2014). One hundred percent conversion of the pollutants was achieved for mono culture of *Bacillus subtillis*at approximately 207 days. Concerning mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*, one hundred percent conversion was obtained at approximately 224 days. The results show that mono culture of *Bacillus subtillis*gives a better result to that of mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*.

CONCLUSION

Based on the result of this research, the following conclusion can be drawn:

The order of reaction for Shinko Drainage Wastewater is referred to as a Shifting order reaction.One hundred percent conversion of the pollutants was achieved at approximately 207 days and 224 days for mono culture of *Bacillus subtillis*and mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*, respectively.Mono culture of *Bacillus subtillis*gives a better result to that of mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*. The MATLAB software is efficient in simulation of Shinko Drainage Wastewater using mono culture of *Bacillus subtillis*and mixed culture of *Bacillus subtillis*and *Pseudomonas aerigunosa*.

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A Comparative Study on HIV-Related Attitude and HIV High Risk Behavior Among Kenyan and American University Students

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A Comparative study on HIV-related attitude toward HIV high risk behavior among university students in Kenya and American Universities

Abstract

The purpose of conducting this research was to investigate the relationship between attitude toward HIV/AIDS and the degree of sexual behavior among university students in Kenya and the United States of America. The sample consisted of 240 university students out of which 121 were from Kenya while 119 were from the United States. Pearson Correlation and Multiple Regression were used to analyze the data. Three hypotheses were tested to find out the relationship between attitudes toward HIV/AIDS as measured by a modified version of the Texas Southern University AIDS Risk Survey Schedule and sexual behavior of targeted college students at the .05 alpha level or better. The findings showed that attitude toward HIV/AIDS contributed significantly to the degree of sexual behavior among university students in the United States independently, and both universities combined but not among Kenya students

Introduction

College students worldwide are at risk for contracting Sexually Transmitted Diseases (STD) AND HIV/AIDS. (Morris, L.A, Ulmer, C., Chimnani J. (2003). Young people, especially university students, are vulnerable due to a general lack of HIV information and prevention services due to their attitude towards HIV/AIDS, condoms and condom use (Emoteso, (2003). In an effort to better understand this vulnerability, this study was designed and executed to assist in developing more specific information from students at two universities with large populations of students with African descent. One university was located in Southern United States, the other in Kenya**. S**pecifically, three research questions were posited :

1. Is there a statistically significant relationship between attitude toward HIV/AIDS and high risk sexual behavior among Kenyan African college students?
2. Is there a statistically significant relationship between attitude toward HIV/AIDS and high risk sexual behavior among United States college students of African descent?
3. Is there a statistically significant relationship between attitude toward HIV/AIDS and high risk sexual behavior among African students in Kenya and college students of African descent in the United States combined?

The HIV-related risk among Kenyan and United States University students would best be understood if their backgrounds are taken into consideration. While in Kenya there are different ethnic groups, in the United States there are different races. There are specific differences between Kenyan and United States university students in areas such as entry into the University, financing of Education and the different ethnicity / races in the different countries (United Nations Education Social and Cultural Organization, 2006 , Sedentricker, (2005)

Kenya

University education in Kenya began in 1963 with just 571 students enrolled in Nairobi University College. Since then, the system has undergone some considerable expansion and as of 2006, there are a total of six public universities and one University college and over 18 private universities with varying levels of accreditation. In total, the country currently has 91,541 students (almost 90 percent of whom are in public universities) (United Nations Educational, Scientific and Cultural Organization, (UNESCO), (2006) With the establishment of education system which takes 8 years in elementary, 4 years in high school and 4 years in the university(8-4- 4there are schools such as medicine and law that take an additional year or two. In addition to the 24 universities and their constituent campuses, higher education in Kenya also includes polytechnics, institutions of science and technology and diploma level teacher training colleges (UNESCO, 2006)

United States

The United States system of higher education on the other hand is unlike most others in that there is no national system. The United States constitution reserves for the states all government functions not specifically described as federal. The states are therefore, principally responsible for the establishment, governance, and regulation of universities and other institutions of higher learning (Sedentricker, (2005). The states license institutions, but they neither accredit nor guarantee the quality of these schools. Instead, the system of accreditation is operated by private, nonprofit organizations (Sedentricker, 2005). In the United States, there are also Minority Serving Institutions. These universities have a historical tradition or mandate to serve a specific demographic of students, but often serve non-minority students as well (http://usinfo.state.gov/scv/Archive/2005/Sep/26-256508 html). Three groups whose members fit into this category are Historically Black Colleges and Universities (HBCUs); the Hispanic Association of Colleges and Universities (HACU); and the American Indian Higher Education Consortium (AIHEC) (Sedentricker, 2005). In some of the United States Universities, there is open enrollment http://www.pbs.org/mediashift/2007/07/open-universities-try- to-bring-college-to-masses2 which is unlike the Kenyan Universities where one has to attain a grade of B and above to get into a university.

Literature Review

Attitude Toward HIV/AIDS Among Students in Kenyan and American Universities

In a study done by Omoteso (2003) to find out about the attitude of university students towards HIV infected students in Nigeria, it was revealed that the attitude of the university students was that of aversion, discrimination and rejection towards Students Living with HIV/AIDS(SLWHA) For example, out of 2106 subjects, 64.50% indicated that it is not safe to have close relationship with a SLWHA, 96% indicated that it is not safe for a student to live in the hostel and that any HIV- infected student should be isolated. 98% indicated that toilet facilities should never be shared with an HIV-infected individual and one must not eat from the same plate with the infected person.

In another study done by Dias, Matos and Goncalves (2005) to 6137 Portugese adolescents to find out the occurance of accurate and inaccurate knowledge about HIV transmission among adolescents, analyses were conducted to examine the way in which variables related to demographic factors, personal characteristics, parent and peer relationships, and school involvement are associated with attitude towards HIV/AIDS-infected people. Results showed that adolescents presented high levels of knowledge about HIV transmission. However, the proportion of young people who hold

misperceptions is also high. A multiple regression analysis identified several associations with attitudes towards HIV-infected persons. The focus groups showed that adolescents believe that people with AIDS experienced discrimination and social exclusion. Adolescents' opinions for HIV-infected persons were mostly positive and tolerant, although some adolescents showed an ambivalent attitude and undefined fears.

Koksal, Namal, Vehid and Yurtsever (2004) did a study of university students in Istanbul, Turkey to investigate the knowledge, attitudes and beliefs amongst students of high school, medical and non-medical school university towards human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS). The results showed that 95% of students were aware of AIDS by its definition and its causation. More than 88% had knowledge that HIV could be detected through blood test. The respondents had the knowledge that HIV infection could be prevented by using condom during sexual intercourse and having sex only with an HIV-negative faithful partner (86%), and with AIDS education (92%). 6-42% of students had misconceptions about transmission and prevention of HIV/AIDS. More than 18% of the students had the attitude that HIV-infected persons should not be allowed to work. In conclusion, the findings of the study suggest that the students have a satisfactory level of essential knowledge on HIV/AIDS. Most of them have good attitudes toward person with HIV/AIDS. However, there are some misconceptions about the routes of transmission.

In a study by Wang Qian (2006) in China, 24 colleges in 19 cities were studied to find out about the attitude toward the disease. The survey results indicated that a more in-depth understanding of AIDS does not necessarily mean having a more positive attitude towards regular medical check-ups, and safe sex. 76.3 percent of students surveyed know how the disease spreads, and 75.6 percent are aware of the various measures that can be taken against infection. However, most of the students surveyed are not aware of the window period, which relates to the time in between infection and effective detection using current testing methods. 57.8% know the general consequences of contracting AIDS in terms of physical well-being, and 47.7% have a basic knowledge of virus detection.

In a study done by Sun, Chang, Niu, Guo & Lu (2004) to find out if prejudice and discrimination against people infected with HIV is a great obstacle to AIDS prevention and control. The study which had 419 first year students from a University in Beijing were class-based randomly divided into the experimental group (Group E) and the control group (group C). Peer education on AIDS prevention was implemented among students in Group E in forms of lectures, playing games, telling stories, role-playing and so on. The results showed that there was no significant differences between two groups before education. The rate of those unsympathetic towards HIV/AIDS was about 25%, while that of avoiding them was 70%. One week after peer education, the attitudes in Group E changed a lot. The rate of unsympathetic students towards HIV/AIDS decreased to 5% and that of avoiding them decreased to 40%. The study therefore indicated that peer education can change students' attitudes related AIDS/condom positively.

In another study by Liying Z. Xiaoming L. Rong, M, Bonita S. Qun Z., Bo W. and Ambika M.(2008) in China, a cross-sectional data was collected from 1,839 students from 19 colleges in Jiansu province of China. The purpose was to show that HIV/AIDS-related stigma has persisted world-wide for decades. This study revealed that there is a high proportion of college students having both stigmatizing attitudes toward people living with HIV/AIDS (PLWHA) and misconceptions about HIV/AIDS transmission routes. Multilevel logistic regression analysis results show that having stigmatizing attitudes towards People Living With HIV/AIDS (PLWHA) is positively associated with having misconceptions about HIV transmission routes. Participants with high misconception scores were more likely to possess stigmatizing attitudes towards (PLWHA)

Condom use has been reported as being highly effective at reducing the risk for HIV infection and other sexually transmitted diseases. How many sexually active partners encourage each other to use condoms during sexual intercourse? There is no specific answer to this question. Research done in the

area of condom use provides some insight into this matter. A few of these studies and their findings are presented below.

An experiment done by Finkelstein and Brannick (2000) showed that an individual's attitude towards condoms and his or her date's attitude both affect how likely they would use a condom in a sexual encounter. Their study measured an individual's attitudes
towards condoms by looking at how uncomfortable they were in discussing condoms
whether or not they believed condoms would interfere with the spontaneity of the moment, and whether or not condoms reduce physical sensation. The most relevant findings in this study are that if an individual has a positive attitude towards condom use, that person will probably use a condom regardless of the date's feelings about condoms

In a study done by McCabe (2004) at the University of Texas at Austin on
Knowledge of HIV, attitudes towards condoms, and condom use among college students, he used forty-four college students, 22 males and 22 females. The age was 18 to 29 years. The researcher had hypothesized that college students who had a positive attitude towards condoms did not use condoms significantly more than college students who had a low knowledge of HIV and a negative condom attitude. This hypothesis was not supported. However, McCabe found that there was no significant difference in how frequently each of these groups used condoms. However, the findings of McCabe that a positive attitude towards condoms does not lead to frequent condom use is not consistent with past research studies that used different measures of attitude toward condoms found that people with a positive attitude towards condoms use them more frequently than those people with a negative attitude towards condoms (McCabe, 2004). One possible reason for this discrepancy is that college students may not be influenced by their attitude towards condoms as much as the participants used in other studies. Another possibility is that this study by McCabe (2004) did not accurately measure frequency of condom use and thus the researcher found no relationship between attitude towards condoms and frequency of condom use.

In another study done by Essien, E. J., Chemeeh, P.E. , Monjoko, E., Ogungbade, G.O. , Balgun, J., Meshaek, A. F., Ward, D., and Holmes, L. (2006) to examine the association between condom use self-efficacy, HIV/AIDS knowledge, as well as attitude towards condom use, a cross sectional observation design was used to obtain information on socio-demographics, HIV knowledge, condom use attitude, and condom use self-efficacy in a sample of one hundred inner city Hispanic youths residing in Houston, texas. A Chi square distribution was used to test the group differences, while logistic regression model was used to assess the association between condom use self-efficacy and the independent covariates. In the unadjusted unvariable logistic regression model, there was a statistically significant association between condom use attitude and condom use self-efficacy prevalence odds ratio (POR), 6.2, 95% confidence interval (CI) = 2.4- 16.5. Likewise, there was a statistically significant association between HIV knowledge and condom use efficacy, POR, 3.4; 95% CI= 1.5-8.2. In the adjusted model, there was a statistically significant association between condom use attitude and condom use efficacy, adjusted prevalence odds ratio (APOR), 3.2, 95% ; CI= 1.2 – 8.5. However, there was no statistically significant association between HIV knowledge and condom use self-efficacy, $p > 0.05$. It was concluded that in this sample of Hispanic youths, attitude toward condom use enhances condom use self-efficacy, whereas HIV knowledge does not predict condom use self-efficacy.

In another study done by Kimondo S.M (2004) to explore the sexual behavior of the male university students, their knowledge, attitudes and use of contraseptives in general and of the condom in particular, probing questions on whether condoms prevented HIV/AIDS resulted in 72.35% answering in the affirmative while 19.8% answered in the negative and 7.85% did not respond. In conclusion, the students had general knowledge of the common STDs including HIV/AIDS but their knowledge of actual symptoms was deficient. Although the attitudes towards condoms are still negative in this population the condom use is higher in this population than any other population.

From these studies, one can conclude that those people who have a positive attitude about condoms are more likely to use condoms and thus are less likely to contract HIV. In the current study, the students also had a positive attitude towards using condoms which is in line with other studies mentioned above.

Methodology

The purpose of this study was to investigate the relationship between attitude toward HIV/AIDS and the degree of high risk sexual behavior among university students in Kenya and the United States of America.

An Historically Black University (HBU) located in a large southeastern city in Texas was used for this study. This University is an open admission university. Students who attend this university range from honor students to below average students. The student body is made up of 9235 Black-non Hispanic, 404 international, 489 Hispanics, 266 whites-non Hispanic, and 422 Asian or Pacific Islanders and other students making a total of 10, 875 as of Spring 2006 (Enrollment Management data, 2006) A large university with almost all ethnic groups in Kenya was used. The population of the students was about 14,000 (University data, 2006). The University is in Nairobi, the capital of Kenya. Students came from all over the

Sample

The sample for this study consisted of 240 university students of which 121 were from the Kenyan university (60 men and 61 women) while 119 were from the HBCU in south Eastern Texas (59 men and 60 women). No attempt was made to generate a representative sample from either University. The sampling goal was to create a sample of each of the four groups that was large enough to test in a statistically robust fashion (parametrically). To control for confounding variables such as major, and class standing, a convenience sampling method of administering the survey in specific courses was used. All students surveyed had completed at least one year at University. This sampling decision was made to ensure that all those surveyed had completed the comprehensive sex education program required of all incoming students.

Sampling Procedure

General courses were identified that are required of all students, regardless of the different disciplines or majors of the students. The sample was representative of the students bodies of each school who take a required general course for all students. In both universities 4 classes were contacted. After contacting the instructors of the courses and receiving permission to visit the class the researcher explained the purpose of the study to the students, who were then invited to participate. All the students participated in completing the questionnaire

The students were then provided a consent form which indicated that they were willing to participate. The students completed the questionnaires in their classes under the supervision of the lead researcher.

The instrument selected was the Texas Southern University AIDS Risk Survey Schedule (TSUAIDSRSS). This instrument was initially developed by Dr. James Essien at the College of Pharmacy and Health Sciences of Texas Southern University in 1996. Several modifications were made to the original instrument for this study. Of the original 77 questions, only 41 were retained.

Rationale for Instrument modifications

The original TSUAIDSRSS contains 77 questions for a total of 208 points. Higher scores on the instrument represent lower risk for HIV. Our revisions were an attempt to make the instrument more international, more population specific (college students) and less time consuming (41 questions, 95 points).

Summary of instrument modifications

The largest revision to the instrument was a reworking of the demographic information. Information on educational level was deleted, in that the target population for this study was college students. Similarly, questions on size and source of income was deleted due to the homogeneity of the population. Age was recorded in years, rather than in the age groups in the original. Had this not been changed, all of our participants would have scored the same age value, negating the usefulness of the variable. Racial / Ethnic information was separated into 2 questions; one US specific, and one Kenyan specific.

The instrument measures total HIV risk, with subscales for Sexual Behavior (BehS), Drug Behavior (BehD), Attitude toward HIV(Att.), Beliefs about HIV (Bel), Knowledge about HIV (Kn), Barriers (Bar), and Information (Info). In our modification we dropped the Barrier subscale (8 questions specific to problems receiving HIV related information and services in Southeast Texas). It was felt that these questions would be too difficult to generalize to international locations. We also dropped the Information subscale (8 questions on the believability of HIV information providers). Again, it was felt that these questions would be too difficult to generalize to international locations.

Contact with the author of the original instrument (Essien, 1996) revealed that no reliability or validity studies have been done. After our modifications, an attempt to measure the fidelity of the modified instrument to the original was made. The weight of each subscale to the total instrument score was analyzed for both the original form (without the deleted subscales) and the modified form. The distribution of subscales (weight of each question to total score) was not significantly different ($p. < 0.05$) between the two test forms (Chi Sq. [5, .05] = 10.85, CV 11.1). The authors acknowledge that the subscale reliability is likely lower than the full scale reliability, yet the extent of this deficit is unknown at present.

Statistical Analysis

For this study only the BehS and Attitude subscales were used.

To analyze data for this study, the multiple correlation and multiple regression procedures were used. According to Kerlinger (1986), multiple correlation analysis is a statistical procedure appropriate for investigating complex inter-relationships between the predictors and criterion variables.

Hypothesis Testing

1. There is no significant relationship found among attitudes toward HIV/AIDS and the degree of high risk sexual behavior among university students in Kenya and the United States. The null was rejected.

Utilizing the Pearson Correlation technique (see Table 1), behavior sex as the dependent variable and attitude as the independent variable were calculated for the students in Kenya alone and a correlation coefficient of 0.194** was realized. The null hypothesis was therefore accepted.

Table 1

Summary Results of the Correlation between Attitude and Behavior among University students in Kenya and the United States

BehS	Procedure	Attitude
	Pearson	0.194**
	Sig. (2-tailed)	0.003
	N	240

**Correlation is significant at the 0.01 level

2. There is no significant relationship between attitude and Behavior Sex among university students in Kenya.

Utilizing the Pearson Correlation technique (see Table 2),, behavior sex as the dependent variable and attitude as the independent variable were calculated for the students in Kenya alone and a correlation coefficient of 0.094 was realized. There was no significant relationship found among attitudes toward HIV/AIDS and the degree of sexual behavior among university students in Kenya. The null hypothesis was therefore accepted.

Table 2

Summary Result of the Correlations between Attitude toward HIV, and Behavior sex Among University Students in Kenya

BehS	Procedure	Attitude
	Pearson	0.094
	Sig. (2-tailed)	0.304 (NS)
	N	121

3. There is no significant relationship found among attitudes toward HIV/AIDS and the degree of high risk sexual behavior among university students in the United States.

Pearson Correlation procedure was applied to behavior sex as the dependent variable and attitudes toward HIV/AIDS as the independent variable (see Table 2) for the US university students and a correlation coefficient of .188* at the .05 level was realized. This indicated that there was a significant relationship found between attitudes toward HIV/AIDS and the degree of sexual behavior among university students in the US. The null was rejected.

Table 3

Summary Results of the Correlation between Attitude toward HIV, and Behavior Sex among University Students in the United States of America.

BehS	Procedure	Attitude
Pearson	.188*	
	Sig. (2-tailed)	.040
	N	119

*Correlation significant at the 0.05 level

Discussion

An interesting finding of the current study was the significant influence of the variables “attitude towards HIV/AIDS” toward the degree of sexual behavior among the university students in Kenya and the US. This was consistent with a study done by Maswanya, Moji, Aoyagi, Yahata, Kusano, Nagata,

Izumi and Takemoto (2000) in which college students in Nagasaki, Japan indicated that they would not have any problem living with, and studying with students who are HIV positive. However, this was unlike a study done by Wodi. B.E. (2005) where the adolescent students appeared insensitive to the plight of their classmates and teachers whose HIV positive classmate or teacher that was not sick should be allowed to attend classes, 41% harbored a negative attitude towards an HIV positive classmate while 19% had no opinion.

Recommendations

The counselors in both countries and universities need to acquire a knowledge base that includes an exhaustive understanding of sexually transmitted diseases as well as HIV/AIDS that has reached epidemic proportions on university campuses. This knowledge should be extended to the students through incorporation of HIV/AIDS education in the university curriculum especially in the foundation study courses.

For Kenyan students, attitudes toward HIV/AIDS does not correlate with high risk sexual behavior. Clearly, counselors need to look elsewhere for areas of intervention. Many of the afflictions suffered in Africa are viewed differently (especially by those outside the educated classes) from how they are viewed in Europe and America. As a whole traditional beliefs and practices are followed more closely than those presented by modern medical and prevention literature. Many of these traditional beliefs have punctuated most of the genuine efforts to tackle the AIDS menace. It may be that education targeting erroneous traditional beliefs would be more useful among this group.

In the US, the counselors need to put more emphasis on behavior change through changing attitudes toward HIV/AIDS. Since many university students do not perceive themselves to be at risk for HIV infection, counselors should provide real life experiences. For example, eliciting the help of college students who are HIV positive may help change the sexual behavioral pattern of US college students.

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ON THE STEADY MHD POISEUILLE FLUID FLOW BETWEEN TWO INFINITE PARALLEL POROUS PLATES

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ABSTRACT

In this paper, we examine the motion of two dimensional steady laminar flow of a viscous Magnetohydrodynamic incompressible fluid between two infinite parallel porous plates under the influence of uniform transverse magnetic field and with constant pressure gradient. Both the lower plate and the upper plates are assumed porous and the fluid enters the flow region through the lower plate and leaves through the upper plate with constant velocity v_o. The resulting coupled differential equations are solved by using finite difference approach. The resulting block tri-diagonal system is solved using Thomas-algorithm and the velocity profiles obtained expressed in terms of Hartmann number.

Key words: MHD flow, Poiseuille flow, numerical methods, Hartmann number, uniform transverse magnetic field.

1. Introduction

Magnetohydrodynamics (MHD) is the fluid mechanics of electrically conducting fluids. The theoretical study of flows in porous media and MHD fluid flows has been on recent years of great interest due to its several applications in geothermal, oil reservoir engineering, separation of matter from fluids, MHD power generation, aerodynamics , astrophysics and environmental applications. Internal flows of MHD fluid in ducts and channels filled with porous media have recieved special attention. Such problems are called transpiration cooling and are effective in reducing heat transfer between fluid and boundary layer with much appllication to cooling of rockets and jets. When an electrically conducting fluid flows through a magnetic field the interaction between the electromagnetic field and hydrodynamics produces magnetohydrodynamics. Some of these fluids include liquid metals such as mercury and molten iron while ironized gases also known as plasma, an example being the Solar atmosphere. MHD in its present form is due to pioneer work of some authors such as Swedish electrical engineer Hannes Alfv´en [1] in 1942, Shercliff [2], Cowling [3]

and Sinha [6]. Palm et al. [7] investigated on the steady free convection in a porous medium and also extended their research work into heat dispersion effect on steady convection in an isotropic porous media. Raptis et al. [9] studied hydromagnetic free convective flow through a porous medium between two parallel plates .Chandra and Prasad [10] analysed the pulsatile flow in circular tubes of varying cross section with permeable wall. Suction and ejection are permissible for the fluid velocity through the wall and flow in a direction normal to the wall. Singh [11] discussed unsteady flow of liquid through a channel with pressure gradient changing exponentially under the influence of inclined magnetic field and solved this by the method of laplace Transform. Al-Hadhrami [12] analysed flow of fluids through horizontal channels of porous materials and obtained velocity expressions in terms of Reynolds number while Ganesh et al.[13] considered unsteady MHD Stokes flow of viscous fluid between two parallel porous plates. They analsed fluid being withdrawn through both walls of the channel at the same rate. Manyonge et al. [14] studied two dimensional Poiseuille flow of an electrically conducting fluid between parallel plates under the influence of transverse magnetic field under a constant pressure gradient and assesed the effect to velocity if the lower plate was porous while the upper plate was not. The resulting differential equation was solved by analytical method and the solution expressed in terms of Hartmann number. In this paper, we examine laminar MHD steady incompressible fluid between two infinite parallel porous plates under the influence of uniform transverse magnetic field. Both the lower plate and the upper plates are assumed porous as the fluid enters the flow region through the lower plate and leaves through the upper plate with constant velocity v_o. The resulting coupled differential equations are solved by using finite difference approach. The resulting block tri-diagonal system is solved using Thomas'-algorithm and the velocity profiles obtained expressed in terms of Hartmann number for various angles of inclination.

2. Mathematical Formulation

The basic concept describing magnetohydrodynamics phenomena can be described by considering an electrically conducting fluid moving with a velocity vector **V.** At right angle to this , we apply a magnetic field, $\mathbf{B}_{app}$**.** We then assume that steady flow conditions have been attained i.e. flow variables are independent of the time t. This condition is purely for analytic reasons so that no macroscopic charge density is being built up at any place in the system as well as all currents are constant in time. Because of the interaction of two fields, namely, velocity and magnetic fields, an electric field denoted by **E** is induced at right angles to both **V** and $\mathbf{B}_{app}$ **(**see figure 1 below**).** This electric field is given by

$$E_{ind} = V \times B_{app} \qquad (1)$$

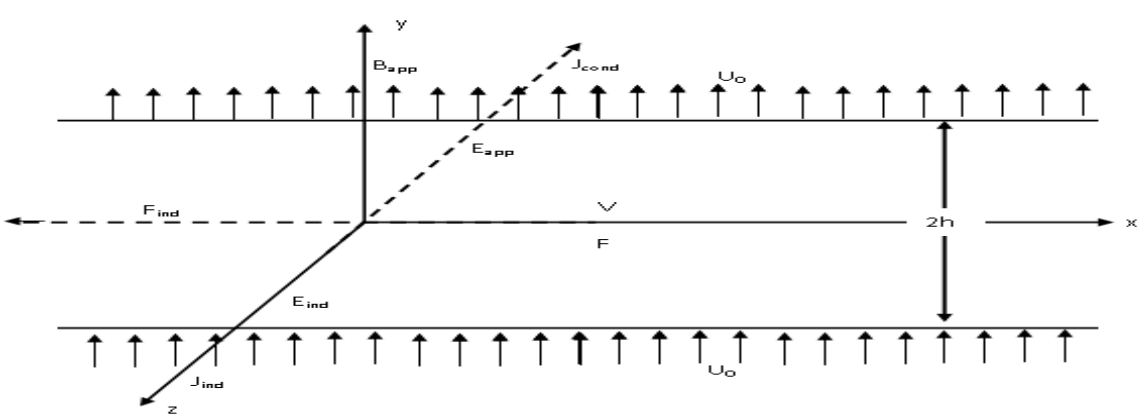

Figure 1. Conceptual Framework of MHD

We assume that the conducting fluid is isotropic inspite of the magnetic field and denote its electrical conductivity by the scalar quantity σ**.** By Ohms law, the density of the current induced in the conducting fluid is denoted by J_{ind} and is given by

$$J_{ind} = \sigma E_{ind} \tag{2}$$

or we can simply write this as

$$J_{ind} = \sigma\ (V \times B_{app}) \tag{3}$$

Simultaneously occurring with the induced current is the induced ponderomotive force or the Lorentz force F_{ind} which is given by

$$F_{ind} = J_{ind} \times B_{app} \tag{4}$$

The Lorentz force is significant in determining the flow profile based on the dimensionless Hartmann number which is given by the ratio of the magnetic body force and the viscous force i.e. Ha = (N.Re)$^{1/2}$, where N =Ha^2/Re =σ .L.B^2 / ρ U stands for the nondimensional interaction parameter known as Stuart number which is defined as the ratio of electromagnetic to inertial forces, and this gives an estimate of the relative importance of a magnetic field of the flow. It is also relevant for flows of conducting fields e.g in fusion reactors, steel casters or plasmas. On the other hand, Re = UL /ν is the nondimensional hydrodynamic Reynolds number, so the Hartmann number can be rewritten as Ha= L.B.(σ / μ) $^{1/2}$ where μ is the dynamic viscosity and ν is kinematic viscosity .

The Lorentz force will occur because, as an electric generator, the conducting fluid cuts the lines of the magnetic field. The vector **F** is the vector cross product of both **J** and $\mathbf{B}_{app}$ and is a vector perpendicular to the plane of both **J** and $\mathbf{B}_{app}$. The induced force is parallel to **V** but in opposite direction. Laminar flow through a channel under uniform transverse magnetic field is important because of the use of MHD generator, MHD pump, crude oil purification and electromagnetic flow meter.

We now consider an electrically conducting viscous, steady , incompressible fluid moving between two infinite parallel plates both of which are kept at a constant distance $2h$ between them. The upper plate and the lower plate are kept stationary. The fluid is acted upon by a constant pressure gradient which makes this flow a plane poiseuille flow.

For zero displacement and Hall currents, Maxwell's equations together with Ohms law and Law of magnetic conservation are written as :

$$\nabla \times E = -\frac{\partial B_{app}}{\partial t} \quad \text{or} \quad \nabla \times E + \frac{\partial B_{app}}{\partial t} = 0 \tag{5}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t} \tag{6a}$$

$$J = \sigma(E + V \times B_{app}) \tag{6b}$$

$$\nabla . B_{app} = 0 \tag{7}$$

$$\nabla . D = 0 \tag{8}$$

where H is the magnetic field intensity vector and D is the electric displacement vector which is analogous to magnetic vector B_{app} .

The governing equations for the flow of incompressible Newtonian fluid that we use in this study are the continuity equation

$$\nabla . V = 0 \tag{9}$$

and the momentum equation :-

$$\rho[\frac{\partial V}{\partial t} + (V.\nabla)V] = -\nabla p + \mu \nabla^2 u + J \times B_{app} \tag{10}$$

where ρ is the fluid density, p is the fluid pressure function, and $J \times B_{app}$ is the Lorentz force. Navier-Stokes equations are differential equations that determine the velocity of the fluid at any instant of time, while Maxwell's equations are differential equations that combine together to form complex equations either magnetic or electric field or both.

In the present analysis , the following important assumptions are made:

i. The fluid flow is incompressible.
ii. The fluid flow is steady hence the flow variables do not depend on time.
iii. The fluid is ellectrically neutral i.e there is no surplus electrical charge distribution present in the fluid.
iv. The only body forces present are lorentz forces.
v. The fluid flow is unidirectional in x-axis , the channel formed by the two plates.
vi. The flow is laminar i.e the flow paths of individual particles of the fluid do not cross those of neighbouring particles , hence, making it possible to follow the path/motion of every individual particle.

The equation of continuity and the momentum equations in two dimensions together with the above assumptions reduces (9) and (10) to the form :

$$\frac{\partial v}{\partial y} = 0 \tag{11}$$

$$0 = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu \frac{\partial^2 u}{\partial y^2} + \frac{F_x}{\rho} \tag{12}$$

$$0 = -\frac{1}{\rho}\frac{\partial p}{\partial y} \tag{13}$$

where F_x is the component of the magnetic force in x-direction. From (11) this implies $v =$ constant or $v = 0$, and since from the flow geometry v cannot be a constant therefore, we choose $v = 0$. From (13) we find that pressure does not depend on y. Hence p is a function of x alone.

3. Non-dimensionalizing of the governing equations

Equations (12) can be non-dimensionalized using the characteristic velocity U , the body length L by denoting the dimensional quantities given as

$$x = \frac{\bar{x}}{L}, \quad y = \frac{\bar{y}}{L}, \quad p = \frac{\bar{p}L^2}{\rho \nu^2}, \quad u = \frac{\bar{u}L}{\nu} \tag{14}$$

and subsequently solving subject to boundary condition $\bar{u} = 0$ when $\bar{y} = \pm L$, where bars denote dimensionless quantities.

Using assumptions (3), (4) and (5), we note that $B_x = B_z = 0$ and $\bar{v} = \bar{w} = 0$ so that, $V_x = \bar{u}i$ and $B_{app} = B_o j$ where B_o is the magnetic field strength component assumed to be applied to a direction perpendicular to fluid motion in $\bar{y}$ - direction , i and j are unit vectors in the $\bar{x}$ and $\bar{y}$ - directions respectively. Now, $F_x = \sigma [(\bar{u}i \times B_o j)] \times B_o j$ from which we find that,

$$\frac{F_x}{\rho} = -\frac{\sigma}{\rho} B_o{}^2 \bar{u} . \tag{15}$$

Using the above dimensionless quantities, equation (12) reduces to $0 = -\frac{1}{\rho}\frac{\partial \overline{p}}{\partial \overline{x}} + \nu \frac{\partial^2 \overline{u}}{\partial \overline{y}^2} - \frac{\sigma}{\rho} B_o{}^2 \overline{u}$ or

$$\frac{\partial^2 \overline{u}}{\partial \overline{y}^2} - \frac{\sigma}{\mu} B_o{}^2 \overline{u} = \frac{1}{\mu}\frac{\partial \overline{p}}{\partial \overline{x}}$$

Or $$\frac{d^2 \overline{u}}{d\,\overline{y}^2} - \frac{\sigma}{\mu} B_o{}^2 \sin(\alpha)\overline{u} = \frac{1}{\mu}\frac{d\,\overline{p}}{d\,\overline{x}} \qquad (16)$$

Where α is the angle between V and B_{app} which means that, the two fields can be assessed at any angle α for $0 \le \alpha \le \pi$.

Differentiating equation (16) w.r.t. x we obtain $\frac{d^2 \overline{p}}{d\,\overline{x}^2} = 0$ and on integration this we obtain $\frac{d\,\overline{p}}{d\,\overline{x}} = -C$ (a constant). With this in mind and dropping the bars (for convinience) we get

$$\frac{d^2 u}{d\,y^2} - \frac{\sigma}{\mu} B_o{}^2 L^2 \sin^2(\alpha) u = \frac{1}{\mu}\frac{d\,p}{d\,x} \quad \text{or} \quad \frac{d^2 u}{d\,y^2} - M^2 u - \frac{1}{\mu}\frac{d\,p}{d\,x} = 0 \qquad (17)$$

Where $M = M^* \sin\alpha$ and $M^* = LB_o\sqrt{\frac{\sigma}{\mu}} = Ha$ and Ha is the *Hartmann* number given by $Ha^2 = \frac{\sigma B_o{}^2 L^2}{\mu}$. Hence equation (17) can be rewritten as

$$\frac{d^2 u}{d\,y^2} - M^2 u + C = 0 \qquad (18)$$

Whose solution subject to boundary conditions

$u = 0 \quad y = -1 \qquad\qquad u = 0 \quad y = +1 \qquad\qquad$ (BC)

was given by Singh (1992) by method of solution of differential equation with constant coeffients as

$$\frac{u}{C} = \frac{1}{M^2}\left[1 - \frac{\cosh My}{\cosh M}\right] \qquad (19)$$

4. MHD Fluid Flow between Two infinite Parallel Porous Plates.

We now consider the MHD steady laminar flow of viscous incompressible fluid between two infinite parallel porous plates separated by a distance $2h$ and x- axis be taken in the middle of the channel parallel to the direction of flow, the y direction perpendicular to the flow , and the width of the plates parallel to the z- direction. The word infinite here means that the width of the plates is large compared with h and hence we treat the flow to be two dimensional. We also take the velocity component w to be zero everywhere and u as function of y alone.

Since both plates have very fine holes distributed uniformly over the entire surface of the plates through which the fluid can flow freely and continously, the fluid will enter the flow region through the lower plate and leave through the upper plate with constant characteristic velocity v_o along y-

direction. For the present steady flow the equation of continuity reduces to $\frac{\partial v}{\partial y}=0$, so that v does not vary with y. Similary, the x and y momentum equations are given by

$$v_o \frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\frac{\partial^2 u}{\partial y^2} \tag{20}$$

$$0=-\frac{1}{\rho}\frac{\partial p}{\partial y} \tag{21}$$

Equation (21) shows that pressure does not depend on y and therefore the equation collapses as p is a function of x alone and so equation (20) reduces to

$$\frac{dp}{dx}=\rho\left[\nu\frac{d^2u}{dy^2}-v_o\frac{du}{dy}\right] \tag{22}$$

Differentiating equation (22) w.r.t. x we obtain $\frac{d^2p}{dx^2}=0$ or $\frac{d}{dx}\left(\frac{dp}{dx}\right)=0$.

Integrating , $\frac{dp}{dx}=-P$ (a constant-say), where the negative sign has been taken to show pressure decreases as x increases. Substituting this, equation (22) now becomes

$$\frac{d^2u}{dy^2}-\frac{v_o}{\nu}\frac{du}{dy}=-\frac{P}{\rho\nu} \tag{23}$$

If the fluid is subjected to uniform transverse magnetic forces, we now model equation (23) by adding the term $(-M^2u)$ to yield

$$\frac{d^2u}{dy^2}-\frac{v_o}{\nu}\frac{du}{dy}+\frac{P}{\mu}-M^2u=0 \tag{24}$$

Let equation (24) be of the form $\frac{d^2u}{dy^2}-A\frac{du}{dy}-M^2u+B=0$ (25)

where $A=\frac{v_o}{\nu}$ and $B=\frac{P}{\mu}$ are constants of the fluid and solve equation (25) by finite difference method under the initial and the boundary conditions

$$u=0 \quad y=-1 \qquad\qquad u=0 \quad y=+1 \tag{26}$$

5. Numerical Solution of the Governing Equation

The non-linear differential equations (25) subject to initial and boundary conditions (26) is solved using finite difference approach. In this technique derivatives occurring in the generated differential equations have been replaced by their finite difference approximations.

An iterative scheme is used to solve the linearized system of difference equations. Central difference approximations have been used because they are more accurate than forward and backward differences. The numerical computation of the generated linearized system of equations based on our step size and results of these are achieved with the aid of MATLAB application software.

Representing the step size by k, the finite difference equation corresponding to equation (25) is given as

$$\frac{U_{i,j+1}-2U_{i,j}+U_{i,j-1}}{k^2}-A\frac{U_{i,j+1}-U_{i,j-1}}{2k}-M^2U_{i,j}+B=0 \qquad (27)$$

where i and j stands for increments in t and y respectively. The block tri-diagonal system is solved using Thomas' algorithm. All calculations have been carried out for $A=1$, $B=2$ and $k=0.25$. Velocity profiles for Hartmann numbers $M*=0.5$, $M*=1.5$, $M*=2.5$ and angle of inclinations $\alpha=15^\circ$, $\alpha=30^\circ$ and $\alpha=45^\circ$ are presented.

6. Results and discussions

Numerical calculations have been performed for velocity profiles. The results are presented graphically in figures (2)-(4) for various Hartmann numbers and different angles of inclinations.

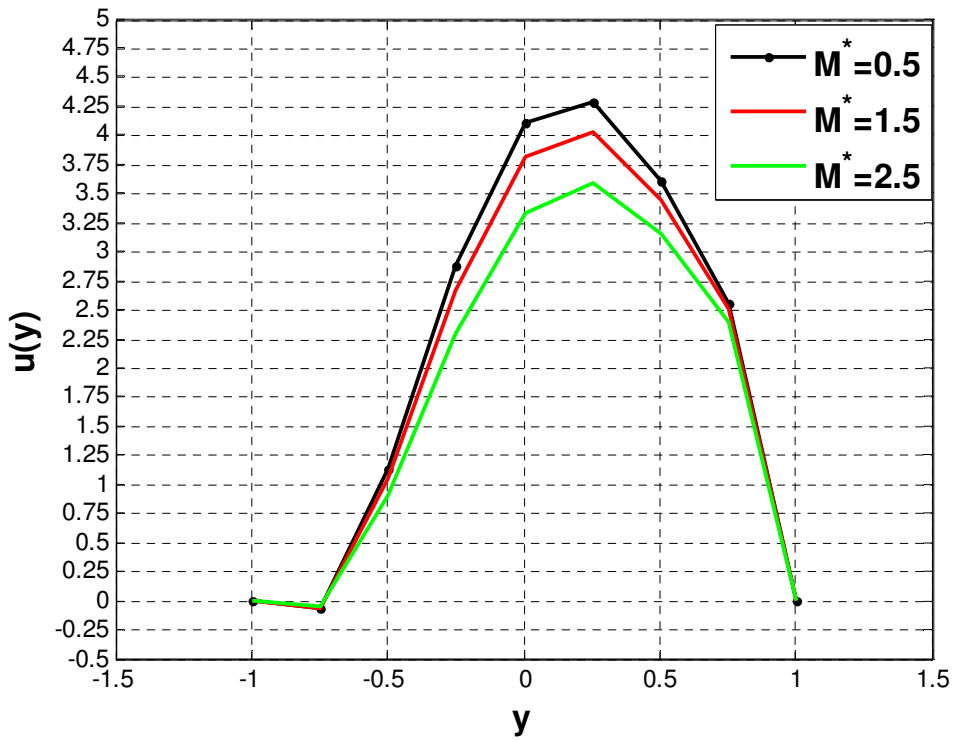

Figure 2: Velocity profiles for various Hartmann numbers for angle of inclination 15^0

7. Conclusions

The steady MHD poiseuille fluid flowing between two infinite parallel porous plates under the influence of tranverse magnetic field and with constant pressure gradient has been investigated. The results from the figures (2)-(4) shows how velocity of the fluid changes with varied Hartmann numbers. An increase in the Hartmann number leads to a decrease in velocity distribution. This is due to Lorentz force generated by the application of constant inclined magnetic field which offers resistance opposing the fluid motion and hence decreasing the flow.

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Cabergoline as a preventive measure against ovarian hyper-stimulation syndrome in assistive reproductive programs

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Abstract. *Ovarian hyperstimulation syndrome is one of the complication appearing not immeddiately but in early phases of pregnancy, in the luteal phase. The aim of this study was to ivestigate the effectiveness of cabergoline in the prevention of severe OHSS, assess its impact on the process of embryo implantation.*

It was observed 192 women receving IVF treatment against infertility and studied the effectiveness of cagergoline in women with early and late forms of ovarian hyperstimulation syndrome.

We determined that the women prescribed cabergoline had fewer reproductive losses against those of the control group and our studies showed that use of cabergoline since the introduction of ovulation trigger decreases early and late types of severe OHSS.

Introduction. One of the most dangerous complications while applying assistive reproductive technologies (ART) during infertility treatment is ovarian hyperstimulation syndrome (OHSS).

Taking into account that ART has become more widespread recently, the risk of OHSS has increased, as well. Generally, major symptoms of this complication appear not immeddiately but in early phases of pregnancy, in the luteal phase.

OHSS is characterized by enlarged ovaries, raised oestradiol to a critical level in blood, redistribution of fluid to a part known as “third space” which in turn may cause development of haemoconcentration, faulty perfusion, and thromboembolism [2,5].

Severe cases constitute 9-15% of all OHSS cases. The cases ending in death are rare. According to info by Wearld Health Organization (WHO), it is 1 in every 50,000 cases [4]. Most of the time what casues them are renal-hepatic failure, cerebral infarction, thromboembolism, respiratory-distress-syndrome. Besides hazards it poses to women, OHSS also creates unfavorable condition for development of implanted embryo [6]. The end-result is frequency of early reproductive losses, most notably in pregnant women with mid and high clinical conditions [2].

There are numerous methods to treat and prevent OHSS but no effective means have been produced yet against OHSS that would not negatively affect frequency of pregnancy, and as well as not cause increase in early reproductive losses. Recently, there have been news regarding use of selective dopamine receptor agonists on D2 receptors (one of which is cabergoline) within treatment and prevention of OHSS [7].

Preventive effect of cabergoline to the risk of development and progression of OHSS is associated with the ability of its specific receptor type 2 (VEGF R2) to block the interaction of vascular endothelial growth factor (VEGF) located on the endothelium, strongly formed by OHSS [1]. The result of the blockade of VEGF effects is reduction in vascular permeability, which helps eliminate the trigger level in the pathogenesis of clinical manifestations of OHSS [1].

It is known that VEGF and VEGF R2 exist in ovarial tissue, namely in granulosa cells and corpus luteum and that VEGF is responsible for the increased vascular permeability. The mechanism of the mentioned process, binding of VEGF and receptor type 2 (VEGF R2), plays a key role in the change in vascular permeability.

Gonadotropins used in IVF stimulation protocols, increase the effect of VEGF R2, which reaches its maximum after the delivery of human chorionic gonadotropin (hCG). In this way, VEGF R2 will be directly correlated with the level of vascular permeability [3].

It was also found that increased delivery of VEGF casuses reduced production of dopamine. Dopamine agonists have the ability to phosphorylate the receptor VEGF R2 and convert VEGF R2

into a form that is not capable of binding with growth factor, a prevention against increase in vascular permeability and the development of OHSS [3, 7]

It noteworthy to state that cabergoline is quite safe in the treatment of patients with prolactinomas and this makes its introduction easier into clinical practice for the prevention of OHSS. However there are certain questions that remain open: what are the criteria for the prescription of cabergoline, in what dosages it should be administered, in what period of controlled ovarian simulation it should be administered, how safe it is in the process of implantation of transferred embryos, how it affects pregnancy rate, and whether there is connection between use of cabergoline and reproductive losses. [4, 8]

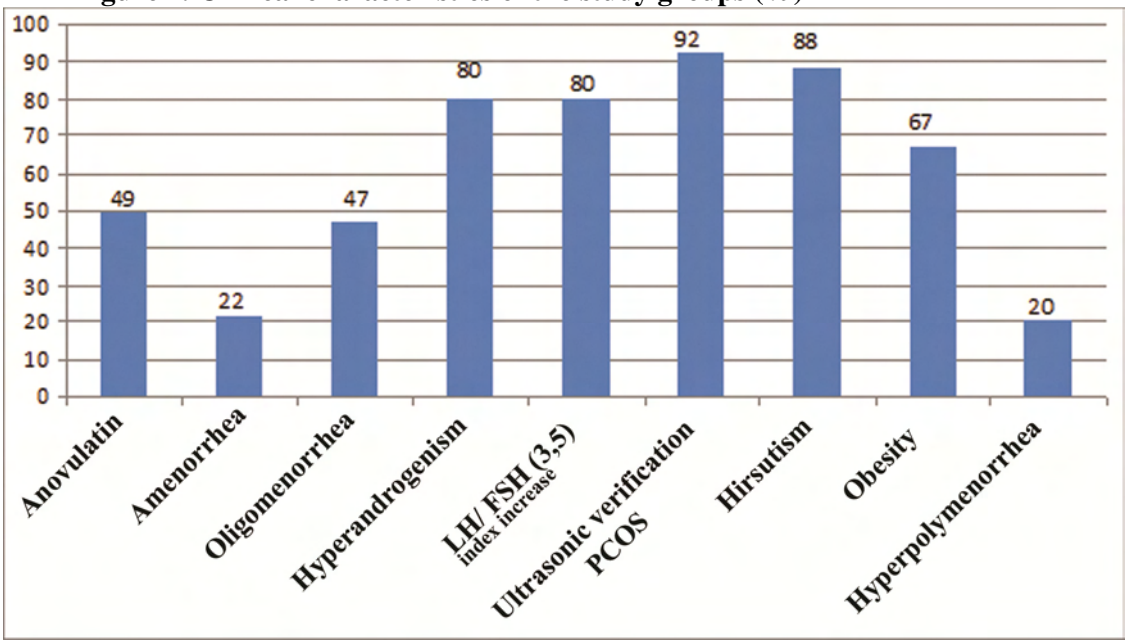
Considering aforementioned points, we have set our goal in this paper: to study the effectiveness of cabergoline in the prevention of severe OHSS, assess its impact on the process of embryo implantation, pregnancy rate and the incidence of early reproductive losses in Azerbaijani population.

Materials and methods: between years 2009 and 2013 192 women receving IVF treatment against infertility were examined at Central Clinic Hospital, Baku. Target group who received cabergoline were 98 people while the control group were 94. In the preparatory phase to IVF, all patients went through standard examinations-which included ultrasonography, hormonal profile on 2-3 days of the menstrual cycle (FSH, LH, TSH, free T4, T3, prolactin, estradiol, testosterone, progesterone, hysterosalpingography (HSG). There has also been examining of the infection status, and evaluation karyotyping. Women with polycystic ovary syndrome (PCOS) were required to undergo glucose load test (100 mg), to determine glycohemoglobin and insulin levels. Controlled ovarian hyperstimulation was performed by standard antagonist protocols, used drugs - Fostimon , Puregon, Bravel, Merional, and Menogon. For ovulation pregnyl, choriomon, and Dekapeptil agonists.

Statistical processing: Obtained results were processed using variations statistics method through the computer software “EpiInfo 7”. While analyzing relative risk level confidence interval of 95% was calculated. While comparing differences, statistical signifance for values of $p<0.05$ was calculated.

Results. All patient groups studied were from 20 to 38 years old, the average age was 29. All patients came to the clinic complaining of infertility, and it was the primary reason for all of them. As shown in figure 1, menstrual dysfunction was observed in 89 patients, and the type oligomenorrhea in 47 (53%), amenorrhea in 22 (25%), hyperpolymenorrhea- 20 (22%). We did not observe dysfunctional uterine bleeding in our patients. Anovulation was diagnosed in 49 patients.

Figure 1. Clinical characteristics of the study groups (%)



Structure of gynecological and somatic diseases was examined. Of gynecological diseases cervicitis and vaginitis were dominant. With regard to somatic diseases the leading diseases were of the gastrointestinal tract.

When any abnormalities prior to the IVF program are identified there is a compulsory treatment of infections, sexually transmitted diseases and TORCH panel infections, as well as correction of hormonal and metabolic disorders following more research and expert advice.

During hyperprolactinemia bromocriptine drugs or dopamine receptor agonists (Dostinex) are prescribed after conducting magnetic resonance imaging (MRI) of the pituitary, and consultation with neurosurgeon and endocrinologist.

During hyperfunction of the adrenal cortex glucocorticoids drugs were administered.

Thyroid dysfunction was eliminated with appropriate medication after ultrasonography of the thyroid gland and consultation with an endocrinologist. After a series of tests and examinations on patients with PCOS who were overweight, had hirsutism, hyperinsulinemia and impaired glucose tolerance, we were able to correct metabolic and endocrine disorders through food diet and drugs that lower body weight, hyperinsulinemia and hyperandrogenism.

Patients received medication of 1000 mg dose "Metformin" or "Siafor" per day during 2-3 cycles. The criteria for the adequacy of the treatment is the reduction in body weight, normalized glucose tolerance test, normalization of glycohemoglobin level and hormonal parameters in blood.

We have also examined the main causes of infertility in our study groups.

Table 1.

Etiological reasons of infertility in target and control groups.

Etiological factors	Control group n=94	Target group n=98
PCOS	44	48
Tubal factor	19	12
Anovulatory cycle	22	27
Idiophathic infertility	9	11

It should be noted that all the women were reported to be with normal uterus, a normal karyotype by ultrasonography. On the Hysterosalpingography (HSG) test

12 women were reported to have one or two-sided hydrosalpinx, to whom during the preparatory phase laparoscopic tubectomy and / or tubal ligation were carried out.

All the husbands of studied patients had normal semen and normal karyotype.

All the patients in target and control groups underwent controlled superovulation simulation due to antagonist protocol.

50patients in the control group of 94, and 54 patients in the target group of 98 - superovulation was carried out with the use of drugs containing human menopausal gonadotropin HMG (menogon, Merional, Menopur) on their 2nd-3rd day of menstruation, for other patients stimulation was started with the use of FSH -containing drugs (Puregon, Fostimon, Gonal-F, Bravel). When the follicles reached diameter of 13-14 mm by about 6-8 days of the menstrual cycle, ie, the day of the treatment FSH antagonists were combined with HMG - containing drugs. As antagonists used daily injections Tsetrotida 0.25 mg or 0.25 mg Orgalutran.

We used hCG and / or agonists (Decapeptyl) as ovulation triggers. The criterion for selection was the number of stimulated follicles and estradiol levels in the blood.

If the number of stimulated follicles was less than 20, and estradiol levels were less than 5000 mol, the patient was administered 10 000 mg hCG. This subgroup, we named *a*.

If the number of stimulated follicles were more than 20, and estradiol levels were less than 5000 mol, two injections of Decapeptyl and 5000 IU hCG were designated for this subgroup we called *b*.

If the number of stimulated follicles were more than 20, and estradiol levels were less than 5000 mol, only two injections of Decapeptyl were designated for this subgroup we called *v*.

For these last two groups, on the day of the appointment of the trigger ovulation patients have begun taking Cabergoline 0.25 mg / day or 0.5 mg / day orally for 8 days. Dose of cabergoline was selected depending on the body-mass-index (BMI) of the patient.

When BMI was less than 25, 0.25mg/day Dostinex was administered while 0.50 mg/day Dostinex was administered for those over BMI of 25.

After embryo transfer all patients were administered progesterone (Crynon gel 8% or Utrogestan 200 mg) and continued to receive till pregnancy was confirmed or denied. If pregnancy was confirmed progesterone was administered till the 14th week of pregnancy.

After the introduction of the ovulation trigger, tracking the signs of OHSS we monitored the overall status of patients till the confirmation / denial of clinical pregnancy by ultrasound,. All cases of OHSS occurring during the first days after the puncture of oocytes were regarded as early OHSS. Cases of all syndromes occurring 9 days after the puncture of oocytes were regarded as late OHSS. Note that at the time of the study, we only considered the cases of moderate and severe OHSS degree classification.

The effectiveness of IVF in the compared groups was assessed by the rate of pregnancy in the stimulated cycle (table 2). Patients with confirmed clinical pregnancy were further tracked in the I trimester, recording the incidence of early reproductive losses (miscarriages and developing pregnancy).

Table 2.

Prophylactic effect of cabergoline in target and control groups..

Analyzed indicators	**Control group n=94**			**Target group n=98**		
	subgroup **a=30**	subgroup **b=30**	subgroup **v=34**	subgroup **a=30**	subgroup **b=30**	subgroup **v=38**
Use of cabergoline	no	no	no	no	yes	yes
Early OHSS (absolute numbers and %)	0 (%) 4 (13,3%)	10 (26,6%)	12 (35,2%)	2 (6,6%)	3 (10,0%)	3 (7,8%)
Late OHSS (absolute numbers and %)	0 (%) 2 (6,6%)	13 (10,0%)	9 (26,2%)	5 (16,6%)	5 (16,6%)	6 (15,5%)

As seen from the table, early and late OHSS cases appear less in target group who used cabergoline than the control group.

B group (early OHSS) RR =0.3 (95% CI 0.09:0.9), p<0.05

B group (late OHSS) RR=0.3 (95% CI 0.13: 0.9) p<0.05

V group (early OHSS) RR=0.2 (95% CI 0.06:0.7) p<0.05

V group (late OHSS) RR=0.4 (95% CI 0.17:0.9) p<0.05

We must also emphasize that cabergoline is relatively more effective means to prevent early OHSS than late OHSS.

As shown on the table 3, target group has much more pregnancy rate than control group. B group RR=0.6 (95% CI 0.4:0.9), p<0.05; V group RR=0.4 (95% CI 0.2:0.7), p<0.05.

Table 3.

Pregnancy rate in IVF patients compared groups based on factor use or non-use of cabergoline..

Analyzed indicators	**Control group n=94**			**Target group n=98**		
	a=30	**b=30**	**v=34**	**a=30**	**b=30**	**v=38**
Use of Cabergoline	no	no	no	no	Yes	yes
Pregnancy rate (absolute numbers and %)	10 (33,3%)	6 (6%)	12 (35%)	10 (33%)	15 (50%)	27 (71%)

It should also be noted that use of cabergoline not only decreases the frequency of OHSS cases but also prevents further development of complications of OHSS. According to our results among women with OHSS, those treated with cabergoline had fewer cases with severe manifestations of OHSS than those patients developing OHSS- who did not use the drug.

Our studies have also shown that the use of cabergoline does not impair the ability to get embryo implantation and does not increase the relative risk of reproductive losses in the first trimester of pregnancy.

As seen from the table 4, target group that were administered cabergoline had fewer reproductive losses against those of the control group: RR=0.5 (95% CI 0.2:0.9) p<0.05.

Table 4.

Reproductive losses in the administration of cabergoline in studied groups.

Analyzed indicators	**Pregnant women who were NOT treated with cabergoline n = 94**	**Pregnant women who were treated with cabergoline n = 98**
Pregnancy loss (absolute numbers and %)	24 (25,5%)	13 (13,2%)

Thus, our studies showed that use of cabergoline since the introduction of ovulation trigger decreases early and late types of severe OHSS, as well as not affect implantation capability of embryo nor increase incidence of early reproductive losses.

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