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BUILDING A TRUSTED HEALTHCARE INFORMATICS PLATFORM: IMPLEMENTATION OF THE ENTERPRISE DATA WAREHOUSE AT THE UNIVERSITY OF MISSISSIPPI MEDICAL CENTER

Denise D. Krause, M.S., Ph.D.
University of Mississippi Medical Center
Jackson, MS 39216

Corresponding Author: Denise Krause dkrause@umc.edu

ABSTRACT

The essential foundation necessary to integrate disparate and heterogeneous data in a large organization is a trusted informatics platform. The University of Mississippi Medical Center is one of many academic health science centers taking strides to build capacity in biomedical informatics and data analytics. The enterprise data warehouse is a vital component to unleash the power of informatics in healthcare, bringing together clinical and financial information from various data sources to identify and analyze data for interpretation. To provide this critical infrastructure and to meet needs across the institution, our main objective was to use open source software and analytics on health-related data to speed the transition of biomedical research into new treatments that improve health outcomes.

The healthcare informatics platform, capable of serving all institutional needs, eliminates the need for disparate data sources housed in silos. The centralized data resource should be governed, not owned, by a well-represented data governance organization. Developing an informatics platform is not a typical IT project. It is a very high-level enterprise initiative that spans all departments and functional areas in the organization. Careful planning and a good implementation are keys to success.

Such a comprehensive institutional data resource can be instrumental in, 1) supporting quality improvement and controlling costs, 2) facilitating research and discovery across datasets, groups, and departments, and 3) providing infrastructure necessary to build the institution's capabilities in biomedical informatics.

INTRODUCTION

Healthcare and health information technology (HIT) are undergoing rapid transformation, as evidenced by the major efforts underway in healthcare systems across the country to replace paper-based records and information silos with comprehensive electronic health records and centralized data repositories. Organizations are expected to make and explore connections in data obtained from a variety of sources. The essential foundation necessary to integrate disparate and heterogeneous data is a trusted informatics platform.

Data are arguably some of the most valuable assets owned by any organization. Establishing a data resource that is trusted is critical to its success. Historically, in large organizations, isolated data "warehouses" have sprung up to serve specific missions or departments. In today's economy, this model is no longer effective, as it typically wastes or duplicates efforts and resources. In order for an organization to more efficiently and effectively leverage its resources and to maximize benefits, it needs to establish an enterprise-wide data warehouse that serves the needs of the whole institution.

The Aberdeen Group, a research and consulting organization in computer and communications research, reported over a decade ago that "the single biggest challenge for next-generation health care providers is to improve on how they consolidate and manage information across the continuum of care."[1] They elaborated further that this "involves building a strategic warehouse of clinical and financial information that can be shared and leveraged by health care professionals, regardless of the location or type of care setting."[1]

Mayo Clinic is one institution that has done much work developing an institutional data warehouse to accommodate data from patient care, education, research, and administrative transactional systems. We have much to gain from the experiences of Mayo and others like them. The Mayo team reported that "the single most important lesson applicable to organizations that seek to emulate Mayo's success with their "Enterprise Data Trust" is to begin with a well-established data governance organization and process that authoritatively represents the institution's interests."[2]

The term enterprise data warehouse (EDW) is not to be confused with a clinical data repository or warehouse (CDR, CDW). The EDW serves a broader function as an open database that brings together clinical and financial information from various sources in order to identify and analyze the data for interpretation[3]. In order to make transactional data useful for retrospective, population-based, aggregate analysis, they must be remodeled for reuse, which is best provided by a separate system[4] -- the enterprise data warehouse.

Such a comprehensive institutional data resource can be instrumental in, 1) supporting quality improvement and controlling costs, 2) facilitating research and discovery across datasets, groups, and departments, and 3) providing necessary infrastructure to build the institution's capabilities in biomedical informatics.[5,6] The University of Mississippi Medical Center is one of many academic health science centers working to align its health IT and informatics strategies to meet these demands.

BACKGROUND

The University of Mississippi Medical Center (UMMC) in Jackson is the state's only academic health sciences center and Level 1 trauma center. Its mission is threefold: to educate future health care providers, to conduct excellence in research, and to provide quality health care. Located in Jackson, UMMC employs more than 10,000 individuals and has six health sciences schools, five hospitals, and a 450-physician multispecialty practice with a common mission: to teach and train the medical professionals of tomorrow and to ensure the future of health care in Mississippi.

Challenges and Opportunities. Vast amounts of data are entered into a variety of source systems each day. This wealth of data presents many challenges. For example, how can data from disparate systems be accessed? Can they be effectively used for research? What are the best approaches to handle legacy data with the implementation of a comprehensive electronic health record (EHR)?

Yesterday's challenges become today's opportunities. A lack of coordinated infrastructure provides the opportunity to design an appropriate, scaleable infrastructure to meet the needs of the entire institution. Disparate clinical information systems are being replaced by a comprehensive electronic health record and an enterprise data warehouse implemented to support all three missions – education, research, healthcare.

UMMC is implementing a MUMPS-based system as a comprehensive EHR. Such systems are known to be very efficient at transactional processing; however, report writing can be difficult and access to data for clinical analyses and for research purposes can be virtually impossible.[7] UMMC's implementation of the EHR includes a clinical data repository in the form of an "operational data store", which will be very useful for on-line analytical processing (OLAP) of transactional data. However, another component is needed to further support research and, more specifically, retrospective, population-based, aggregate data analysis. The EDW takes data from the CDR, as well as data from many other legacy source systems, and external datasets, to provide access to current and historical information from multiple source systems.

To provide this critical infrastructure and to meet needs across the institution, our main objective was to use open source software and analytics on health-related data to speed the transition of biomedical research into new treatments that improve health outcomes. Our specific aims were to:

1.   Create a data warehouse platform, known as MARTS (Mississippi Academic Research in the Translational Sciences), to integrate clinical and biomedical data for translational research.

2.   Provide a portal for investigators and knowledge workers to access clinical and translational research resources, to track usage and outcomes, and to provide support to empower employees to make informed decisions and solve problems, thus creating strategic leverage for the organization.[8]

METHODS

This type of large-scale initiative requires strong executive sponsorship, a large budget commitment, and availability of resources. Having established this commitment at UMMC, a Request for Proposals was written to initiate a three-phase project to develop the EDW. In parallel, we researched data warehousing hardware solutions capable of storing and processing massive amounts of data. Having discovered that some of our peer institutions were dissatisfied with their proprietary solutions due to performance, cost, and/or licensing issues, we ultimately opted for a PostgreSQL open source database platform running open source analytical tools. Furthermore, we chose a massively-parallel processing (MPP) data warehousing environment new to health care in order to position UMMC for the future by ensuring adequate performance for growing data volumes.

We solicited customer buy-in from all areas of the institution – hospital administration, clinical care, finance, research, institutional review board, education, compliance, legal, and information systems. A wide-scale internal marketing campaign was orchestrated to educate

future customers on the potential uses and implications of the establishment of a trusted healthcare informatics platform. Interviews were used to identify key personnel who might be willing to serve on data governance / oversight committees.

We agree with Mayo that defining a data governance organization is essential to the success of a trusted informatics platform. The EDW should not be owned by any individual, group, department, or mission, but rather, governed by committees with representation across the institution. Working committees that report to an executive committee should be responsible for many operations. These include determining definitions to be used in the EDW, setting priorities, determining which data to load, how data are accessed and by whom, establishing policies and procedures, and developing business agreements and data use agreements. Working committees should represent specific interests, such as data stewardship, clinical informatics, and research informatics.

RESULTS

Basic architecture of the platform is illustrated in Figure 1. Bringing source data from disparate systems into a centralized location allows for querying across multiple platforms. It provides an ideal platform for storing data from legacy systems, both for historical archives and for phasing out systems that are no longer needed. Using this "single source of truth" for quality purposes ensures better data are available for research and clinical purposes.

DISCUSSION

Establishing the infrastructure upon which to build a healthcare informatics platform is not only a daunting undertaking, but can also be a very costly and lengthy proposition. An enterprise-wide strategy for data warehousing provides state-of-the-art, scaleable architecture to accommodate the institutional needs, while consolidating and coordinating financial and human resources. The EDW utilizes the data from the EHR and complements the CDR, extending both of their capabilities further to support quality and research. The EDW becomes the "single source of truth," replacing multiple data repositories and their conflicting reports. This centralized data source saves time and resources by allowing the data to be cleaned one time and re-used many times. In decentralized environments, data are cleaned and tucked away neatly in their silos. Hence, efforts and resources are often duplicated.
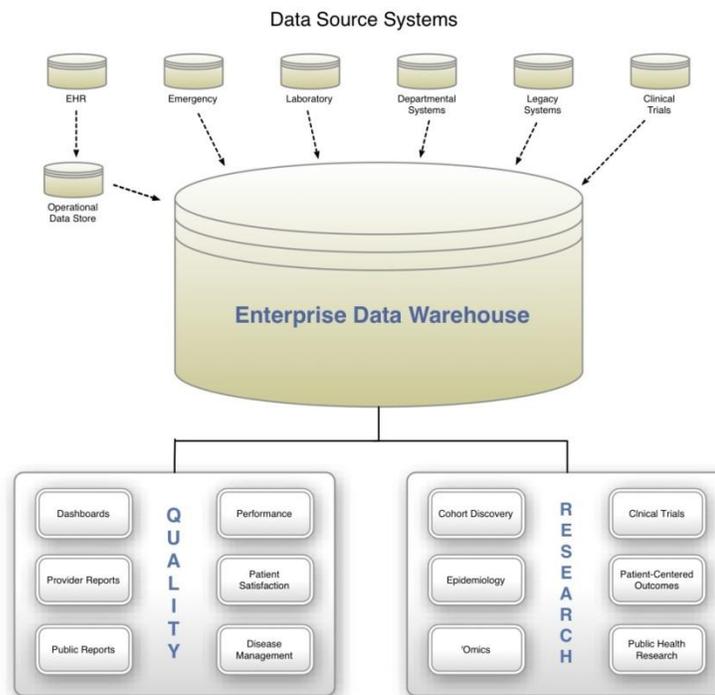

Figure 1. Basic architecture of the trusted healthcare informatics platform.

Implementing a data governance organization with all groups represented, as suggested by our colleagues at the Mayo Clinic,[2] helps to balance out conflicting interests. Data governance is critical in determining the various definitions that will be used, such as how diabetes is defined, and resolving differences when they arise. It also serves to protect and maintain data integrity. Establishing the healthcare informatics platform as an institutional resource with a health data governance organization is the first step in empowering employees to make informed decisions and solve problems to the benefit of the organization. If an organization can achieve this, it will tap into a wealth of readily available resources.

LESSONS LEARNED

In summary, we learned from peer organizations, as well as through our own experiences, that:

- building a trusted healthcare informatics platform is not a typical IT project. It…
  "spans all departments and functional areas within any given enterprise. The result, more often than not, is a huge political war and power struggle over who 'owns' what data contained within…a data warehouse"[9]. This is a very high-level enterprise initiative. It involves IT, but affects everyone in the organization.

- The informatics platform should be built as a resource to serve all institutional needs, thereby eliminating the necessity for disparate data sources housed in data silos.
- The centralized data resource should be governed, not owned. A well-planned data governance organization will help ensure that the resource is not controlled by any one group or area, thereby becoming a silo in itself.
- Careful planning and implementation are essential. The right people should be represented and involved throughout the project. Good organization is a "must" to keep up the momentum of a monumental project and to keep high-level professionals engaged.
- One of the first steps is to define and develop a comprehensive data model that is inclusive, but flexible, to accommodate future needs.
- Data should be transformed into information, using standard vocabularies and ontologies.

Careful planning and implementation of this type of mission-critical initiative enables organizations to leverage the wealth of data that they generate each day. A poor implementation or lack of data governance can have significant adverse effects on achieving success.

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FOOD DIGESTION BY SUBTERRANEAN TERMITES FROM THE SOUTHEASTERN UNITED STATES (ISOPTERA: RHINOTERMITIDAE)

Tim J. Arquette[1,2]

[1] Mississippi State University South Branch Experiment Station, Poplarville, MS
[2] Mississippi State University Departments of Biochemistry, Molecular Biology, Entomology, and Plant Pathology, Mississippi State, MS

Corresponding Author: Tim Arquette tja68@msstate.edu

INTRODUCTION

The majority of termite species in the United States are economically important, with the eastern subterranean termite (*Reticulitermes flavipes* Kollar) and the Formosan subterranean termite (*Coptotermes formosanus* Shiraki) particularly serious threats to wooden structures (Su and Scheffrahn, 1990). Other subterranean termites (family Rhinotermitidae) found in the southeastern U.S. are *Reticulitermes virginicus* Banks, *R. hageni* Banks, and a species that received formal recognition recently, *R. malletei* Clement.

Termites are designated as either lower or higher termites based on differences in the digestive system. Specifically, lower termites harbor flagellate protozoa in the digestive tract that digest wood cellulose and hemicelluloses, while higher termites do not. The core food of lower termites is dead wood, with a preference for partially rotted wood (Noirot and Noirot-Timothee, 1969). Most termite species in the United States are lower termites.

Wood contains very little nitrogen. Lower termites obtain dietary nitrogen from nitrogen-fixing bacteria that inhabit the hindgut, as well as from uric acid digested by other bacteria harbored there (Breznak and Brune, 1994). Cannibalized termites are a source of uric acid for these bacteria, as well as stores mobilized from fat body (Breznak, 2000). Dietary nitrogen may also be present from other foods besides wood. Chitin, ingested by termites from cannibalism as well as from fungi in decayed wood, would provide the insect with dietary nitrogen if digestible (Waller and LaFage, 1987). Protein is contained in termite feces (Nation, 2002; Arquette et al., 2012) and may provide dietary nitrogen, as termites are coprophagous.

As the most abundant wood carbohydrate, cellulose is the main food of lower termites. It is a straight-chain polysaccharide made up of glucose molecules covalently bonded by beta linkages. Hydrogen bonding occurs between parallel cellulose molecules, resulting in a crystalline structure (O'Sullivan, 1997). This structure makes cellulose indigestible for most organisms. Efficient degradation of crystalline cellulose to glucose requires a combination of three enzymes. These are endoglucanases, exoglucanases, and beta glucosidases (Nation, 2002). Bacteria, protozoa, and fungi are among the few organisms that produce each of these enzymes. Termites synthesize endocellulase and beta glucosidase, but not exocellulase. Endocellulase produced by lower termites may increase the efficiency of wood digestion by protozoan symbionts harbored in the hindgut (Nakashima et al., 2002), and may even degrade some cellulose without exocellulase (Slaytor, 2000). Wood polysaccharides other than cellulose are collectively termed hemicelluloses, mainly xylan or mannan, and also require multiple enzymes for digestion.

Wood particles take about 24 hours to pass through lower termite gut (Breznak, 1982), most of that time being digested in food vacuoles of hindgut flagellate protozoa. These flagellates digest most wood cellulose eaten by termites (Trager, 1932; Hungate, 1938), and digest wood hemicelluloses as well (Yoshimura, 1995; Smith et al., 2007), but not much lignin (Yoshimura, 1995). If the flagellates are eliminated from the digestive tract, the insect soon starves. Bacteria, archaea, and yeasts are other microorganisms harbored in termite gut, some of which digest cellulose (Li et al., 2006).

Overall cellulase activity is measurable with a cellulosic substrate such as filter paper (Urbanszki et al., 2000). Individual enzyme activities can also be measured using substrates including carboxymethyl cellulose for endocellulase, and cellobiose for beta glucosidase. The dinitrosalicylic (DNSA) reducing sugar assay is commonly used for determination of sugars released from cellulase as well as hemicellulase activity assays.

While many protozoa are free-living, the flagellate protozoan symbionts of lower termites are only found in the digestive tract of their host. Types of flagellates vary between termites. For instance, *Coptotermes fomosanus* harbor three flagellate species. The largest, *Pseudotrichonympha grassi,* is found more at the forward region of hindgut. These engulf and digest cellulose and other wood polysaccharides, and expel undigested lignin via exocytosis (Yoshimura, 1995). *Hodomastigitoides hartmanni* is about evenly distributed through the hindgut (Lai et al., 1983). Dietary requirements for *H. hartmanni* appear to be different than for *P. grassi,* which cannot survive a diet of low molecular weight cellulose. *Spirotrichonympha Liedyi* is diminutive in size, and tends to occur in highest numbers toward the rectum. Rather than engulf wood particles, this species has been hypothesized to obtain dissolved nutrients from hindgut fluid (Yoshimura, 1995).

Past studies described changes in wood structure upon passage through lower termite gut from light microscopy as well as scanning and transmission electron microscopy (Yoshimura, 1995; Yamaoka and Nagatani, 1977). These studies reported changing shape of wood passing through the gut, the size and type of food engulfed and digested from protozoa, and the time taken for gut transit. Wood particles ingested by Formosan termites are less than 100 μm in length (Yoshimura, 1995; Itakura et al., 1995). Smaller wood particles have more surface area (Watanabe and Tokuda, 2001) and are increasingly porous during digestion, giving additional areas upon which digestive enzymes can act (Matsumura et al., 1977).

Animals must quickly excrete excess nitrogen from breakdown of protein and purines. For insects, nitrogenous wastes are primarily ammonia or uric acid (Cochran, 1985; Chapman, 1998). Ammonia is usually the major nitrogenous waste produced by insects that live in aquatic or very moist environments. For insects that live in dry habitats, need to conserve body weight for flight, or have a dry diet, uric acid is typically the main nitrogenous waste (Chapman, 1998; Cochran, 1985). Types of nitrogenous wastes in insect feces have been determined for various orders. Blattaria is the best studied, with varying proportions of uric acid and ammonia identified for many cockroach species (Cochran, 1985). Uric acid also accumulates in cockroach as well as termite fat body, a process termed storage excretion (Chapman, 1998). Many cockroaches harbor uricolytic bacteria in their fat body that digest uric acid from adjacent storage sites (Cochran, 1985). Termites also store uric acid in fat body, but only one species, *Mastotermes darwiniensis*, harbors uricolytic bacteria there. For other termites, uric acid stored in fat body can only be digested if it is mobilized to the hindgut for digestion by uricolytic bacteria in the gut fluid (Potrikus and Breznak, 1980a and 1980b). Such uricolytic bacteria, identified so far only from *Reticulitermes flavipes* hindgut, likely digest most uric acid that reaches them (Potrikus and Breznak, 1980a and 1980b). Laboratory populations of *R. flavipes* can store uric acid in fat body in very high quantity (Potrikus and Breznak, 1980a and 1980b; Arquette et al., 2006), and would provide a substantial source of dietary nitrogen if mobilized to the hindgut for digestion. However, there is disagreement as to whether uric acid stores in fat body are mobilized or remain there permanently as a product of storage excretion (Breznak, 2000; Slaytor and Chappell, 1994; Slaytor, 2000).

Cellulose and chitin are the most abundant biopolymers in nature (Merzendorfer and Zimoch, 2003). Both are straight chain polysaccharides, with glucose subunits comprising cellulose and N-acetylglucosamine for chitin, linked together by beta 1, 4-glycosidic bonds. A main difference between cellulose and chitin is that cellulose contains no nitrogen, whereas chitin is about 7 percent nitrogen, which could be utilized in the termite's metabolism if digested (Waller and LaFage, 1987). Like cellulase and hemicellulase, multiple enzymes work together for chitin digestion. Chitinase is produced by insects at the time of molting, and is also found in the digestive tract of some insects. Examples include chitinase activity measured from labial glands of *Acromyrmex octospinosus* (Febvay et al., 1984) and from larvae and adults of a microphagous beetle species (Fukamizo et al., 1985). Chitinase has been determined to be present in the digestive tract of a few termites (Noirot and Noirot-Timothee, 1969; Mishra and San Sarma, 1981), but not others (Mishra and San Sarma, 1981).

The efficiency of food digestion by insects has been reported in numerous studies, for example by grasshoppers (Phillippe, 1991). Digestive efficiency of insects can be determined from comparing the amount of food eaten with that remaining undigested in feces. For termites, efficiency of lignocellulose digestion has been reported for *C. formosanus* and other species (Itakura et al. 1995; Hyodo et al. 1999; Mishra and Sen-Sarma 1979; Katsumata et al. 2007). Digestion of wood components for Formosan termites was reported based on assay of fecal material recovered from pine blocks and surfaces of laboratory arenas (Itakura et al. 1995; Hyodo et al. 1999). However, another study demonstrated Formosan termites held in similar conditions chew pieces from wood blocks without eating them, with accumulated wood particles impossible to separate from feces (Arquette, 2011).

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WOOD DEGRADATION IN THE DIGESTIVE TRACT OF THE FORMOSAN SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE)

Tim J. Arquette[1, 2], Amanda M. Lawrence[2, 3], Blair J. Sampson[4], and Jose M. Rodriguez[5]

[1] Mississippi State University Formosan Termite Research Laboratory, Poplarville, MS
[2] Mississippi State University Department of Biochemistry, Molecular Biology, Entomology, and Plant Pathology, Mississippi State, MS
[3] Mississippi State University Electron Microscope Center, Mississippi State, MS
[4] USDA Agricultural Research Service, Poplarville, MS
[5] State Chemical Laboratory, Mississippi State, MS

Corresponding author: **Tim Arquette** tja68@msstate.edu

INTRODUCTION

Most wood decomposition in the digestive tract of subterranean termite workers (family Rhinotermitidae) occurs in food vacuoles of flagellate protozoan symbionts in the hindgut (Radek, 1999). Types of protozoa vary between termite species. Formosan subterranean termites (*Coptotermes formosanus* Shiraki) harbor three different flagellates, each occupying a different niche in the hindgut (Lai et al., 1983). *Pseudotrichonympha grassi,* the largest, engulfs wood particles and digests cellulose and other polysaccharides (Yoshimura, 1995). *Hodomastigitoides hartmanni* also engulfs wood, but appears to have different dietary requirements than *P. grassi*, which is not able to digest low molecular weight cellulose (Yoshimura, 1995). *Spirotrichonympha leidyi*, a much smaller species, obtains dissolved nutrients from gut fluid (Yoshimura, 1995). Some wood carbohydrate may also be digested before reaching the hindgut by enzymes produced in termite tissue (Radek, 1999). The current study aimed use scanning electron microscopy to analyze the degree of degradation of wood particles in different regions of *C. formosanus* gut.

MATERIALS AND METHODS

Coptotermes formosanus workers used for this study were from a colony collected at Audobon Park in New Orleans, LA. Insects were kept in polystyrene containers (Tri-State Plastics, Latonia, KY) containing weathered yellow pine blocks, approximately 20 cm x 4 cm x 1 cm, at 28º C and saturated humidity. Dissection of whole guts was carried out as described in Zhou et al. (2007). Excised guts were transferred to a piece of nonstick aluminum foil placed on dry ice. A double-edged razor blade was used to subdivide guts into foregut, midgut, forward hindgut, middle hindgut, and rear hindgut as illustrated in Lai et al. (1983). Quick cutting with the blade sealed gut sections containing fluid with ingested wood particles. Three sets of 10 foregut and

midgut sections, and three sets of five hindgut sections, were gently squeezed with forceps in microcentrifuge tubes containing distilled water. Tubes were stored overnight at -20º C before further processing. To remove salts in the gut fluid that would coat wood particles during drying, thawed samples were centrifuged twice for 5 minutes at 7,000 g with one change of distilled water, followed by 5 minutes at 20,800 g after an additional change of water. Tubes were vortexed and two drops immediately transferred with a disposable pipette to scanning electron microscope stubs. Stubs had a piece of carbon mounting tape affixed, with a grid pattern cut onto the tape with a razor blade. Squares of grids were approximately 0.5 mm^2. Stubs were air dried under a fume hood, sputter coated, and wood particles viewed with a Zeiss EVO-40VXP environmental electron microscope. Micrographs were obtained at 2,000 x magnification for five different areas within a square on the grid. This was repeated for five different squares of the grid.

Degree of wood degradation was determined from comparing the number of apparent holes in wood particles recovered from each gut section. Holes were defined as fully enclosed areas on a wood particle darker than the surrounding particle surface and longer than 10 μm. One-way ANOVA and Tukeys HSD was carried out using SAS software (SAS Institute) to identify significant differences in numbers of holes in wood particles between gut regions.

RESULTS

Electron micrographs showed a variety of shapes and sizes of wood particles recovered from all gut sections (Figures 1-5). The Tukey's HSD test shows wood from the middle and rear hindgut was significantly more degraded than particles from the fron foregut and midgut (Figure 6).
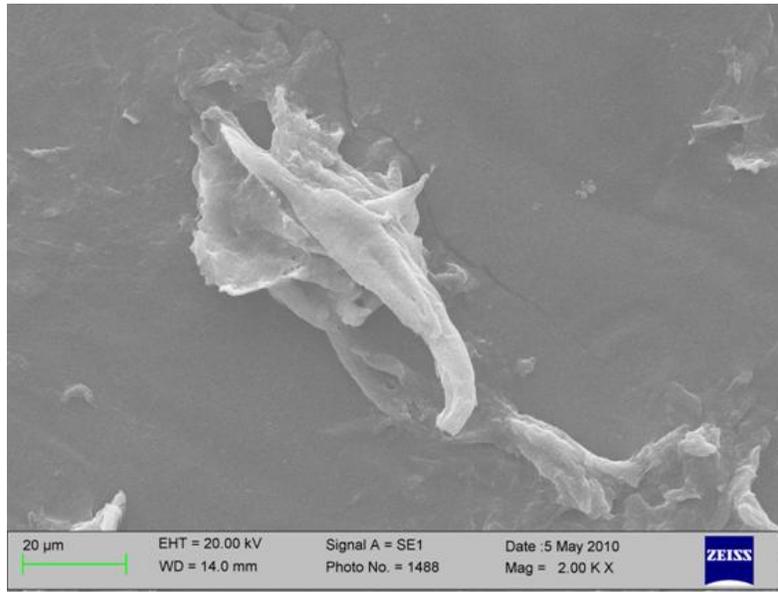
Figure 1: Scanning electron microscope image of particles recovered from *C. formosanus* foregut
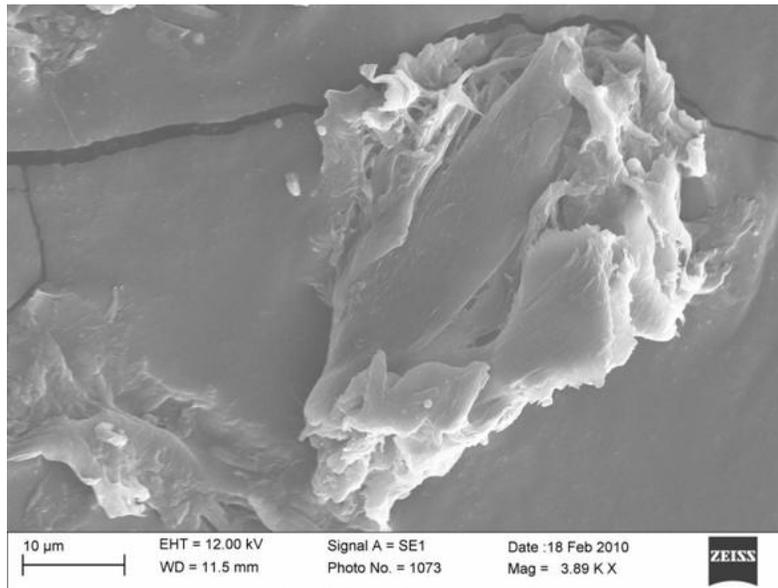
Figure 2: Scanning electron microscope image of particles recovered from *C. formosanus* midgut
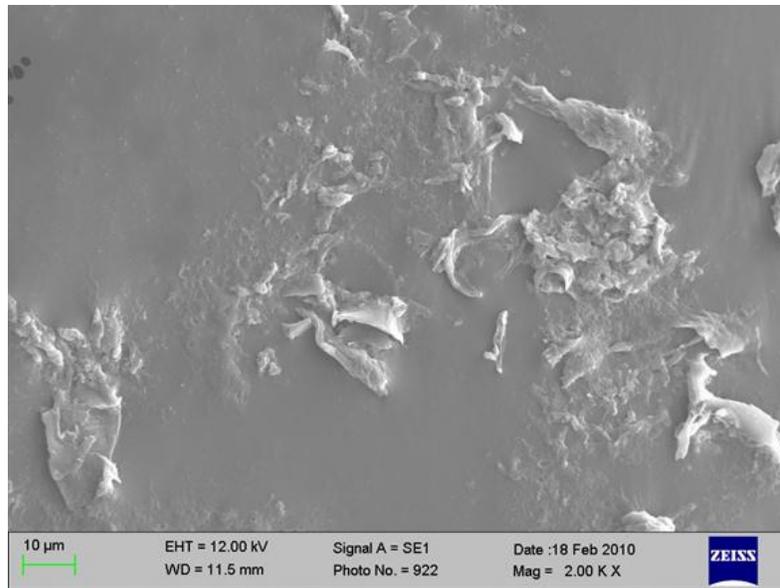
Figure 3: Scanning electron microscope image of particles recovered from the forward section of *C. formosanus* hindgut
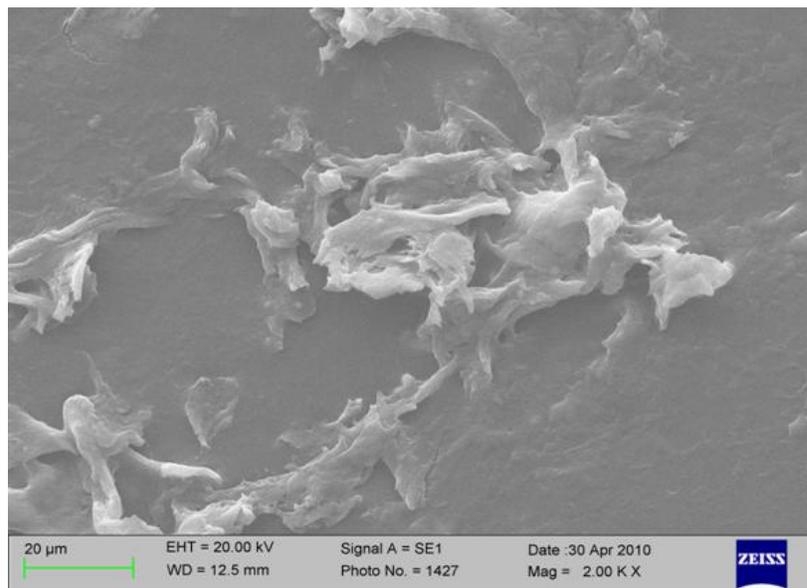
Figure 4: Scanning electron microscope image of particles recovered from the middle section of *C. formosanus* hindgut
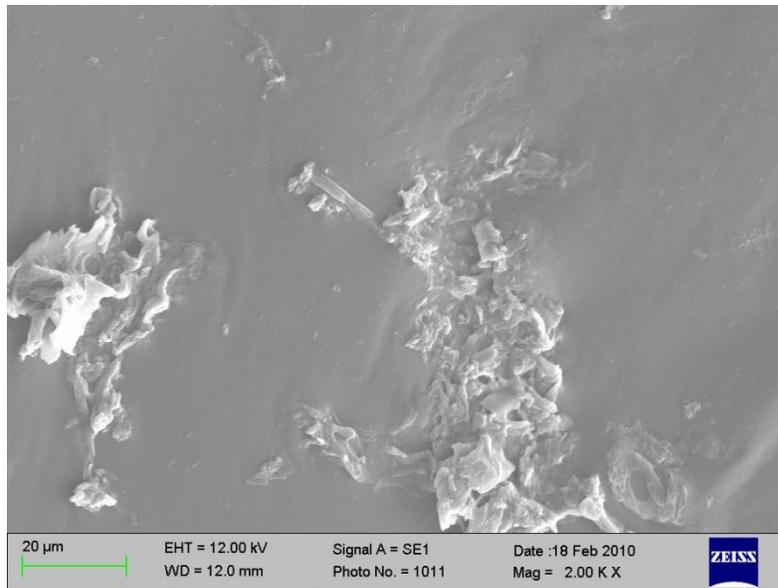
Figure 5: Scanning electron microscope image of particles recovered from the rear section of *C. formosanus* hindgut
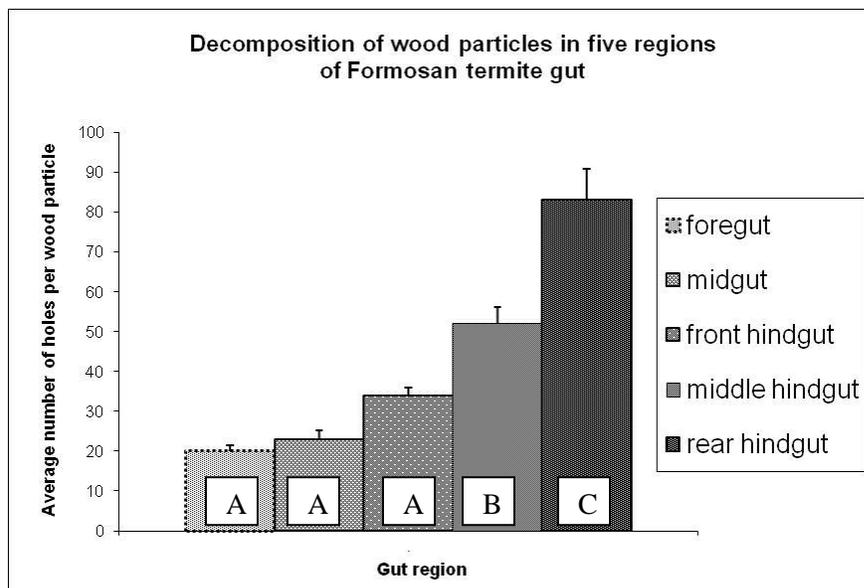
Figure 6: Average number of holes in wood particles recovered from five regions of
C. formosanus digestive tract, + the standard error of the mean. Numbers of wood particles counted per gut section: foregut 128, midgut 196, front hindgut 150, middle hindgut 133, rear hindgut 155. Different letters denote a significant difference in number of holes by Tukey's HSD test.

DISCUSSION

Fluid from insect hindgut can generally be regurgitated to the midgut and foregut. For termites, however, this is not possible as the enteric valve prevents backflow to the midgut (Noirot and Noirot-Timothee, 1969). Wood particles in the hindgut would therefore be expected to be much more degraded compared to forward gut sections. This was apparent from significantly higher

numbers of holes in wood recovered from the middle and rear sections of the hindgut. More *P. grassi* and *H. hartmanni* are found in combination at the front of the hindgut compared with the middle and rear sections (Lai et al., 1983). Wood degradation at the front hindgut from its digestion by these symbionts could explain the significantly higher numbers of holes in particles from middle and rear hindgut sections. Although some wood is theoretically digested from the action of endocellulase and beta glucosidase released from termite salivary glands and midgut epithelial cells (Slaytor, 2000), numbers of holes were not significantly different except in the hindgut, Figure 6), indicating little digestion had occurred in foregut and midgut. Different explanations of how wood is digested in lower termite digestive tract have been published. Some authors, such as Slaytor (200) and Yoshimura 91995), submit cellulolytic enzymes produced in termite tissue degrade woor in forward gut sections. However, results of the current study indicate wood decomposition chiefly occurs in the hindgut. This supports the long-held conclusion that wood digestion in lower termites is carried out maily by masses of symbiotic protozoa that inhabit the hindgut (Noirot and Nirot-timothee, 1969)

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WATER QUALITY STUDIES OF GROUNDWATER IN OWERRI, NIGERIA

Peter U. Okorie[1], Alex D.W. Acholonu[2] and C.J. Onyemaechi[1]

[1] Department of Animal and Environmental Biology,
Imo State University, P.M.B. 2000, Imo State, Nigeria.

[2]Department of Biological Sciences, Alcorn State University,
Alcorn State, MS 39096, U.S.A.

Corresponding Author: Alex D.W. Acholonu, chiefacholonu@alcorn.edu

ABSTRACT

There is growing worry about the possibility of groundwater contamination in oil producing areas of Nigeria as a result of intensified oil exploitation and other human activities. This study of chemical parameters of groundwater in Owerri was carried out as part of a general evaluation and monitoring of water quality characteristics of groundwater in Imo State of Nigeria. Borehole water samples from four sites of potentially different hydrological characteristics were analyzed for chloride, dissolved oxygen, silica, ammonia, pH, hardness, phenolphythalein alkalinity, carbon dioxide, nitrate, phosphate, zinc, iron and chromate. None of the water quality parameters tested exceeded the World Health Organization (WHO)/ Environmental Protection Agency (EPA) water quality thresholds. Also the water chemical characteristics showed remarkable similarities in the four sites, except for hardness and chloride contents which showed differences in the locations. Recommendations are made on firm government regulations on exploitation of groundwater resources.

INTRODUCTION

Groundwater, defined as the body of water derived from percolation and contained in permeable rock formation known as aquifers (Ayoade, 1988), is an important source of public water supply in many countries. It constitutes about 28% of the public water supply in Nigeria and as much as 99% in Austria and 65% in the Netherlands (Table 1)

Table 1: Sources of Public Water Supplies in Selected Countries

Country	Surface Water %	Groundwater%	Artificial Recharge %
Fed. Rep of Germany	8	61	31
The Netherlands	20	65	15
Sweden	56	29	15
Austria	1	99	-
England and Wales	62	38	-
USSR	70	30	-
USA	83	17	-

Groundwater is generally held to be of high water quality standards because when water passes into the aquifer, either from fall precipitation or seepage from stream channels, it loses its suspended matter, pathogenic bacteria and undesirable odor or taste as a result of bio-filtration process at the water aquifer interface (Kazmann, 1965).

But considering the various sources of recharge and discharge of groundwater, taking into consideration various anthropogenic influences like mining activities, groundwater should not be generally assumed to be pollution-free. The present study was carried out in Owerri municipality which lies on the northern fringe of Niger Delta basin of Nigeria, an area of intense oil exploration and exploitation activities, and Awaka I Owerri North Local Governtment Area (LGA).

There is growing public apprehension of groundwater contamination by crude oil, especially in view of the large number of oil spills from pipelines in Nigeria. In 1999, for instance, there were 319 oil spills in the Niger Delta which released about 23,377 barrels of crude oil into the environment (SPDC, 1999).

The Shell Petroleum Development Company of Nigeria alone uses some 400 km^2, or about 0.6% of the land area of Niger Delta, for such activities as construction of wells, installation of pipelines and preparation of waste disposal sites. Thus the entire area is potentially vulnerable to contamination of both surface and groundwater resources.

In previous studies (Okorie and Acholonu, 2008; Okorie *et al.,* in press), two important rivers in the recharge/discharge hydrological cycle of groundwater in Owerri, namely, Nworie River and Okitankwo River, had been studied and their hydrochemistry documented. The present study aims to establish some water quality characteristics of groundwater sources in Owerri. Previous data on groundwater sources in Owerri were highly limited in scope in terms of the chemical parameters as they were usually commissioned by individual borehole owners. It is therefore hoped the present study will provide a useful baseline data for further monitoring of groundwater sources in the area.

This study aims to establish some water quality characteristics of ground water sources in Owerri.

Previous data on groundwater sources in Owerri were highly limited in scope in terms of the chemical parameters as they were usually commissioned by individual borehole owners.

MATERIALS AND METHODS

Three sampling sites in Owerri, the capital city of Imo State of Nigeria, and the fourth at Awaka, were chosen for this study (Figures 1 and 2).
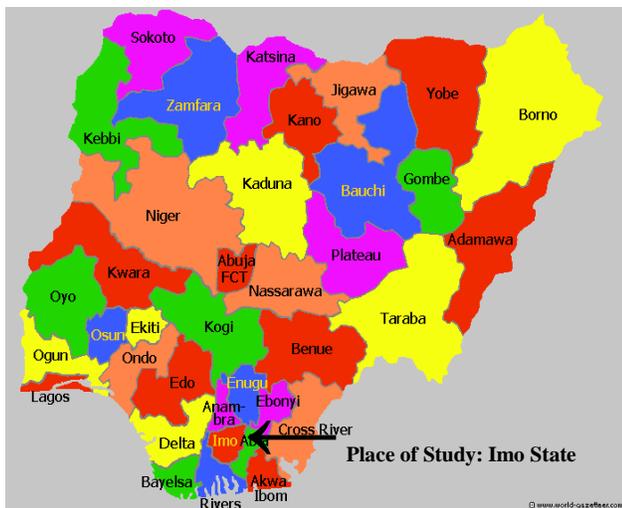
Figure 1: Map Showing Study Area
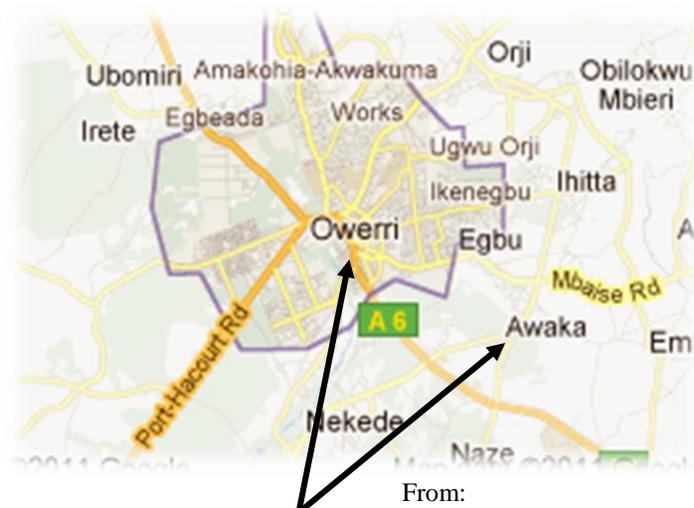
From:

maps.google.com
Owerri, Awaka, Imo State
Study Location

The groundwater samples were collected from borehole taps (Figure 3), and the water samples were taken immediately to the laboratories and tested for contaminants. The samples were tested with La Motte chemical pollution test kits following operational guidelines of the manufacturer. The physical and chemical parameters tested were odor, color, turbidity, magnesium hardness, calcium hardness, phenolphthalein alkalinity, chloride, dissolved oxygen, silica, ammonia, carbon dioxide, nitrate, phosphate, zinc, iron and chromate. The results were compared with World Health Organization (WHO) and Environmental Protection Agency, U.S. (EPA) standards for drinking water.

Figure 3 Shows work being done on the borehole at Awaka

RESULTS

The physical characteristics of the groundwater samples are presented in Table 2. All samples were clear and odorless as expected in all ground waters of sufficient depth.

Table 2: Physical Characteristics of Groundwater Samples in this Study (Site 4, same)

Parameter	Site 1	Site 2	Site 3
Odor	Odorless	Odorless	Odorless
Color	Colorless	Colorless	Colorless
Turbidity	Clear	Clear	Clear

Table 3 compares the chemical properties of the groundwater with World Health Organization (WHO) and Environmental Protection Agency, USA (EPA) water quality standards.

In all the parameters tested, the groundwater samples generally did not exceed the thresholds of WHO/EPA water quality standards.

The only exceptions were total hardness (in one of the sites) and dissolved oxygen (Figure 4).

Table 3: Chemical properties compared with WHO/EPA standards

| Parameters	Sampling Site 1 (Owerri)	Sampling Site 2 (Owerri)	Sampling Site 3 (Owerri)	Sampling Site 4 (Awaka)	WHO/EPA Standards
pH	5.3	6.0	5.5	5.5	6.5 – 9.0
Total hardness	8.0	64.0	8.0	23.0	50
Magnesium hardness	8.0	34.0	8.0	N/A	N/A
Calcium hardness	0	30	0	N/A	N/A
Phenolphthalein Alkalinity	0	0	0	3.4	3.08
Chloride	10.0	6.0	8.0	N/A	250
Dissolved oxygen	6.5	6.0	6.4	6.1	4.0 – 5.0
Silica	0	0	0	4.8	75
Ammonia	<1.0	<1.0	<1.0	0.1	N/A
Carbon Dioxide	9.2	9.0	9.5	13.7	10.0
Nitrate	<0.2	<0.2	<0	1.7	10.0
Phosphate	<0.2	<0.2	<0.02	0.3	0.1
Zinc	<1.0	<1.0	<1.0	1.6	15
Iron	<0.5	<0.5	<0.5	N/A	1
Chromate	<0.1	<0.01	<0.01	N/A	0.05

N/A--test not performed
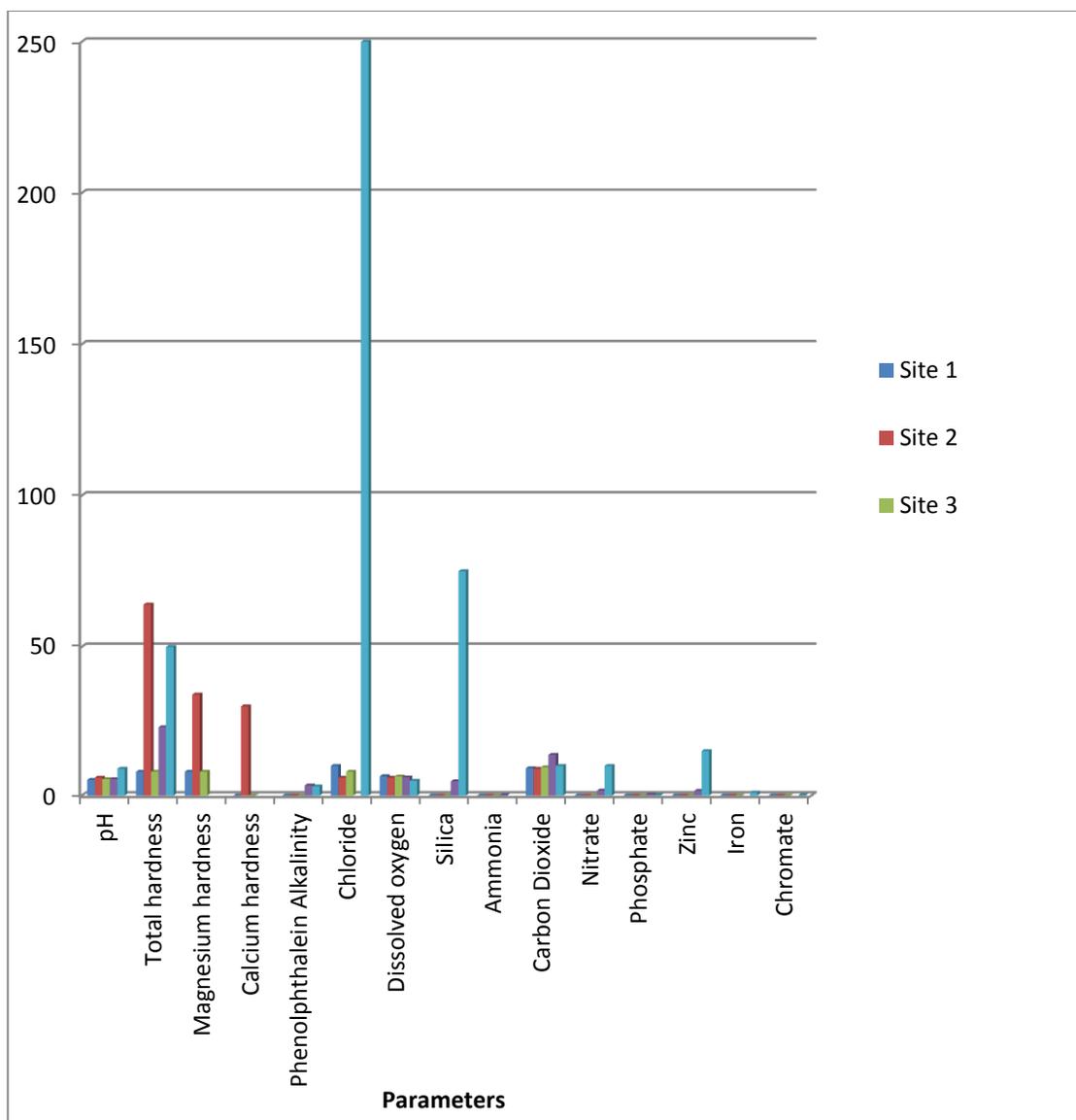
Figure 4. Graph Showing Results of Chemical Parameters Tested.

DISCUSSION

The values of the chemical parameters of the groundwater were lower than the threshold in all the cases except total hardness and dissolved oxygen.

Since the hardness of groundwater generally exceeds that of surface waters (Ayoade, 1988), this result is not surprising. Hardness signifies the presence in water of divalent metallic cations such as calcium and magnesium. Water hardness results from the solution of carbon dioxide released by bacterial action in the soil in the percolating rainwater. This solution dissolves carbonates in the soil and rock therefore converting them into soluble bicarbonates.

The lower dissolved oxygen value of the surface water, Nworie River, when compared to the groundwater is to be expected. A previous study (Okorie and Acholonu, 2008) had clearly established that Nworie River was facing substantial organic pollution, as was obvious from the high values of carbon dioxide and ammonia contents of the river (Table 4). In this circumstance, dissolved oxygen will inevitably be steadily depleted by the decay process resulting in low concentrations of dissolved oxygen. Also worthy of note is the spatial variation of hardness and salinity in the sampling sites.

Table 4: Physico-chemical characteristics of ground water compared with a natural water body (Nworie River)

*Parameter	Groundwater Sampling Station I	Groundwater Sampling Station II	Groundwater Sampling Station III	Groundwater Sampling Station IV	Nworie River
PH	6.0	5.5	5.3	5.5	5.5
Total hardness	64	8.0	8.0	23.0	8
Magnesium hardness	34	8.0	8.0	N/A	2
Calcium hardness	30	0.0	0.6	N/A	6
Phenolphthalein Alkalinity	0	0	0	3.4	N/A
Chloride	6.0	8.0	10.0	N/A	16
Dissolved Oxygen	6.0	6.4	6.5	6.1	1.4
Silica	0	0	0	4.8	0
Ammonia	<1.0	<1.0	<1.0	0.1	1
Carbon Dioxide	9	9.5	9.2	13.7	14.2
Nitrate	<0.2	<0.2	<0.2	1.7	0.2
Phosphate	<0.2	<0.2	<0.2	0.3	N/A
Zinc	<1.0	<1.0	<0.2	1.6	0
Iron	<0.5	<0.5	<0.5	N/A	N/A

N/A--test not performed
*Except pH, all the volumes are in ppm (parts per million).
+Source: Okorie and Acholonu (2008)

Though all the sampling sites can be classified as soft waters, the samples from sampling station II, which fell in-between the areas of higher elevation (I) and lower elevation (III), showed a high value of total hardness that exceeded WHO/EPA drinking water standards.

However, generally speaking, spatial variations in groundwater quality are usually due to variations in the chemical composition of the aquifer.

Salinity generally increases with depth (Ayoade, 1988). A common geochemical sequence in groundwater includes bicarbonate waters near ground surface while chloride waters predominate in the deepest layers of aquifers.

Thus salt content of groundwater can vary from less than 23 ppm in a quartzine spring to over 300,000 ppm in brines (Todd, 1980).

Overall, it is safe to conclude from this study that groundwater resources within the Owerri municipality and Awaka are still free from contamination, both from inorganic pollutants expected from petroleum production as well as organic pollutants resulting from refuse disposal and other human activities. There is need for enforcement of government regulations on sitting of boreholes. It is necessary that all proposed sites for borehole wells must first be inspected and approved by the relevant agencies.

If the site satisfies the criteria, then licenses will be issued before sinking of the boreholes by certified hydrologists/water engineers.

These results generally confirm the generally held view that groundwater, especially when they are extracted from the requisite depth, are of high drinking water quality.

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FIRST RECORD OF TARDIGRADA FROM THE ISLANDS OF SAINT THOMAS AND SAINT JOHN, U.S. VIRGIN ISLANDS, WEST INDIES

Harry A. Meyer

Department of Biology and Health Sciences,
McNeese State University, Lake Charles, LA 70609

Corresponding author: Harry Meyer, hmeyer@mcneese.edu

ABSTRACT

The terrestrial tardigrade fauna (Phylum Tardigrada) of the West Indies are poorly known. In the Greater Antilles only Puerto Rico, the Dominican Republic, and Grand Cayman have been surveyed to any extent. Seven samples of moss and foliose lichen collected in December 2011 contained forty tardigrades and two eggs, representing three genera and five species: *Milnesium* sp., *Macrobiotus harmsworthi*, *Macrobiotus* cf. *echinogenitus*, *Paramacrobiotus* cf. *areolatus* or *tonollii*, and *Paramacrobiotus* cf. *richtersi*. The *Milnesium* specimens are from an undescribed species. They resemble *Milnesium tardigradum* in having claw configuration [2-3]-[3-2], six peribuccal lamellae, a smooth cuticle, and accessory points on primary claw branches, but differ in having a having a more narrow posterior margin of the buccal tube and smaller claws relative to the length of the buccal tube.

INTRODUCTION

Tardigrades (Phylum Tardigrada), commonly known as water bears, are microscopic animals found in marine, freshwater, and terrestrial habitats. Terrestrial species occur in mosses, lichens, liverworts, and leaf litter, and are renowned for their ability to enter a cryptobiotic state (anhydrobiosis) in response to desiccation. The first investigations of water bears (Phylum Tardigrada) in the West Indies were made in the mid-Twentieth Century, when du Bois-Reymond Marcus [1] found four species in the Netherlands Antilles. Since then there have been few studies of terrestrial and freshwater tardigrades from the islands of the Caribbean Sea. These studies have been limited to Puerto Rico [2-5], the Dominican Republic [6-7], Cuba [8], and Grand Cayman [9] in the Greater Antilles, and Curaçao [1], Los Testigos [1], Saint Lucia [10], Dominica [11] and Barbados [12] in the Lesser Antilles.

Saint Thomas and Saint John, United States Virgin Islands, are two islands in the Greater Antilles. The islands are volcanic in origin and very hilly. They are tropical in climate, averaging about 1000 mm of rainfall a year. Prior to human settlement, most of Saint Thomas and Saint John was covered by subtropical dry forest and subtropical moist forest [13]. This paper contains the first record of tardigrades from these two islands.

METHODS

Observations and Data

Sampling was conducted on December 28 and 29, 2011. One foliose lichen and two moss samples were collected from trees at Drake's Seat on Saint Thomas (18°21'41" N, 64°57'04"W; 262 m elevation). Four samples were collected on Saint John: one foliose lichen from a tree and one moss from a stone at Annaberg Plantation (18°21'33"N, 63°44'08"W; 10 m elevation), one moss from a rock alongside Pastory Road (18°19'55"N, 63°47'13"W; 77 m elevation), and one moss from rock alongside Jumbie Beach Trail (18°21'05"N, 63°46'25"W; 6 m elevation). Samples were stored in sealed paper envelopes. In the laboratory samples were soaked in water overnight, thereby rehydrating anhydrobiotic water bears. After sieving (42 µm mesh diameter), the samples were examined with a dissecting microscope. Tardigrade specimens and eggs were mounted on slides in polyvinyl lactophenol. Sample processing was completed by early February 2012.

Specimens are archived in the W.A.K. Seale Museum, McNeese State University; Lake Charles, Louisiana 70609, USA (slides SMLA 9950–9957).

RESULTS

RESULTS

A total of forty specimens and two eggs were present, representing three genera and five species. The number of species in a sample ranged from zero to four. No

tardigrades were found in material from Jumbie Beach Trail or the moss from Annaberg Plantation.
The following species were present:

Milnesium sp.
Drake's Seat, Saint Thomas: two females (foliose lichen). Annaberg Plantation, Saint John: eight females, one male (foliose lichen).
The presence of *Milnesium tardigradum* has been widely reported in the West Indies. However, Michalczyk et al. [14], in a review of the genus *Milnesium* Doyère, 1840, concluded that *Milnesium tardigradum* sensu stricto can only confidently be asserted to occur in Europe, and that records from other regions must be confirmed. They recommended that all earlier records of *Milnesium tardigradum* be re-classified as *Milnesium* sp. or *Milnesium* cf. *tardigradum* until reappraised. Using their criteria, earlier published records of *M. tardigradum* from the West Indies (Curaçao, Grand Cayman, Dominican Republic, and Saint Lucia) should now be reassigned to *Milnesium* sp., either because the provided description differs significantly from *M. tardigradum* sensu stricto or because insufficient description is provided to make a determination.
Milnesium specimens from Saint Thomas and Saint John represent an undescribed species that will be described elsewhere. They resemble *Milnesium tardigradum* in having claw configuration [2-3]-[3-2], six peribuccal lamellae, a smooth cuticle, and accessory points on primary claw branches, but differ in having a having a more narrow posterior margin of the buccal tube and smaller claws relative to the length of the buccal tube.

Macrobiotus harmsworthi Murray, 1907
Drake's Seat, Saint Thomas: 18 specimens and two eggs (foliose lichen and moss). Meyer and Hinton [12] found *Macrobiotus harmsworthi* on Barbados; du Bois-Reymond Marcus [1] noted the presence of *M.* cf. *harmsworthi* in Los Testigos.

Macrobiotus cf. *echinogenitus* Richters, 1904
Drake's Seat, Saint Thomas: one specimen (foliose lichen). Annaberg Plantation, Saint John: four specimens (foliose lichen). The *Macrobiotus echinogenitus* species complex is cosmopolitan, and eggs are required for specific identification. Du Bois-Reymond Marcus [1] found *M.* cf. *echinogenitus* on Curaçao.

Paramacrobiotus areolatus (Murray, 1907) or *P. tonollii* (Ramazzotti, 1956)
Drake's Seat, Saint Thomas: one specimen (foliose lichen). Without eggs these two species cannot reliably be distinguished. In the West Indies *P. areolatus* has been recorded in the Dominican Republic [6] and on Grand Cayman [9].

Paramacrobiotus cf. *richtersi* (Murray, 1911)
Pastory Road, Saint John: five specimens (moss). The *Paramacrobiotus richtersi* species complex is cosmopolitan, and eggs are required for specific identification. In the West Indies *P. richtersi* has been reported from the Dominican Republic [6], Saint Lucia [10], Grand Cayman [9], and Barbados [12].

DISCUSSION

This collection offers only a preliminary look at the tardigrade fauna of Saint Thomas and Saint John; it should not be considered a comprehensive survey. Among the islands of the West Indies, only Grand Cayman, Hispaniola (Dominican Republic portion), and Puerto Rico have been systematically surveyed for terrestrial tardigrades. No survey, including this one, has collected freshwater tardigrades; when such habitats are included in West Indian sampling the number of recorded species will doubtless increase.

CONCLUSIONS

Four of the five species of terrestrial tardigrade collected in the U.S. Virgin Islands belong to cosmopolitan species or species groups. All are known to occur elsewhere in the West Indies. *Milnesium* sp. is an undescribed species in a genus where until recently all specimens were routinely assigned to *Milnesium tardigradum* [14]. Meyer and Hinton [12] described a new species of *Milnesium* from Barbados; reexamination of *Milnesium* specimens collected from other Caribbean islands using current taxonomic criteria may well uncover new species.

ACKNOWLEDGMENTS

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Division: History and Philosophy of Science

O7.16
4:30   BIOLOGICAL INDIVIDUALS, TIME, AND PERSISTENCE: THE PERDURANTIST FOUNDATIONS OF THE SPECIES-AS-INDIVIDUALS THESIS

August W.M. Martin, Independent Scholar

The species-as-individuals (SAI) thesis accentuates issues of time and persistence in the ontology of biological individuals in virtue of its grounding in a perdurantist view of persistence and further assumptions that it makes about other biological entities such as cells and organisms. Perdurantism holds that entities, biological and otherwise, possess temporal parts and not just spatial parts. The opposing view of persistence is endurantism, which holds that entities are whole and complete at each moment they exist and possess only spatial parts. Thus, the SAI thesis views species as four-dimensional entities (or more informally, as "spacetime worms"), spread out in three dimensions of space and one dimension of time. What is more, the SAI thesis holds that the kind of individuality that species exhibit is also possessed by all other biological entities; thus, the view of persistence underlying the SAI view of species is extended to the whole of biological ontology. This claim was initially made by David Hull (1978), explicitly drawing on a perdurantist notion of the biological individual advanced by T. H. Huxley (1852), who held that an "individual animal is the sum of the phenomena presented by a single life". This notion has been carried forward by other SAI theorists, such as Horvath (1997). Purchasing the SAI thesis entails accepting a perdurantist view of all biological entities, events and processes, and therefore an ontology that I maintain is not already accepted by most biologists.

Division: Health Sciences

Posters will be presented at both 1-4 and 6-8 pm divisional poster sessions
P6.03
SUSTAINED RELEASE OF MANNITOL FROM TRICALCIUM PHOSPHATE DRUG DELIVERY DEVICE
Zack Watson[1], Courtland Brown[2], Michelle Tucci[2], and Ham Benghuzzi[2]
1Mississippi State University and 2University of Mississippi Medical Center, Jackson, MS 39216

Mannose, an isomer of glucose, is thought to aid in the healing of certain tissues, including tendons, when directly applied to the affected area. Sustained delivery of Mannose, or closely related sugars, is believed to substantially aid in the repair process and quality of certain tissues compared to those tissues treated directly. In this experiment, Mannitol, a sugar similar to Mannose, was encapsulated in fifteen porous, ceramic drug delivery devices of which three were shams, six were filled with 0.05g Mannitol, and six with 0.1g Mannitol. A delivery profile was found after soaking the capsules in sterile PBS for one week. The concentrations of released Mannitol were checked each day at noon. A graph of the concentration data did reveal a sustained release pattern with the sham showing no delivery, the 0.05g Mannitol showing a delivery of 3 micrograms/day over seven days, and the 0.1g Mannitol showing 4.5 micrograms/day over seven days. It was found that the capsules containing 0.05g Mannitol released 21 micrograms over the seven day period and the capsules containing 0.1g Mannitol released 31.5 micrograms over the seven day period. This shows that doubling the dosage does not necessarily mean doubling the amount delivered per day; rather, an increased dosage would be able to deliver a slightly larger amount for a longer period of time than the smaller dosage. This data shows that the device was successful in achieving a sustained delivery pattern. Subsequent tests on cells and later on larger, more complex models should be carried out to reveal the effects of this sustained release on living organisms.

P6.04
THE EFFECTS OF MANNOSE 6-PHOSPHATE AND MANNITOL ON MCCOY FIBROBLAST CELLS

Zack Watson[1], Courtland Brown[2], Michelle Tucci[2], and Ham Benghuzzi[2]
[1]Mississippi State University and [2]University of Mississippi Medical Center, Jackson, MS 39216

Mannose, an isomer of glucose, is thought to aid in the healing of certain tissues, including tendons, when directly applied to the affected area. Sustained delivery of Mannose, or closely related sugars, is believed to substantially aid in the repair process and quality of certain tissues compared to those tissues treated directly. In this experiment, the effects of Mannitol and Mannose-6-Phosphate were tested on McCoy fibroblasts. Two phases were performed: a direct delivery phase and a sustained delivery phase. In each phase, two well plates were used. Phase I yielded favorable results for the controls. For Mannose, the cell counts reached a peak at 48 hours and then declined. For Mannitol, the cell counts were inversely proportional to time. In Phase II, all controls and 24 hour cells were normal, but those cells treated with Mannose and Mannitol at 48 and 72 hours appeared morphologically and organizationally different. There are a few possibilities for this difference; however, it was seen that these cells began to organize into matrices or tissues. This organization suggests that the sustained delivery speeds the organization and repair of the cells, causing them to begin forming tissues just after 72 hours. This expedited organization caused by the sustained delivery is seemingly beneficial to the cells; however, further testing on cells and more complex models should be carried out to ensure the safety of this process.

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Ms. Barbara Holmes
Mississippi Academy of Sciences
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