

AFRICAN JOURNAL OF CHEMICAL EDUCATION

AJCE



Vol. 13, Number 1, January 2023

SJIF Impact Factor Evaluation [SJIF 2012 = 3.963]

SJIF Impact Factor Evaluation [SJIF 2013 = 4.567]

Indexed and Abstracted by CAS



A Publication of

ISSN 2227-5835

www.faschem.org

AFRICAN JOURNAL OF CHEMICAL EDUCATION

AJCE

Editorial Board

Editor-in-Chief **Temechegn Engida**
UNESCO-International Institute for Capacity Building in Africa
ETHIOPIA

Associate Editors **Ahmed Mustefa**
Department of Chemistry, Addis Ababa University
ETHIOPIA

Dereje Andargie
Institute of Education, Debre Birhan University
ETHIOPIA

Belina Terfasa
Department of Chemistry, Kotebe University of Education
ETHIOPIA

Sileshi Yitbarek
Department of Chemistry, Kotebe University of Education
ETHIOPIA

International Advisory Board

Prof. Peter Mahaffy, King's University College, CANADA
Prof. John Bradley, University of the Witwatersrand, SOUTH AFRICA
Prof. Ameen F.M. Fahmy, Ain Shams University, EGYPT
Prof. Hassimi Traore, University of Wisconsin – Whitewater, USA
Prof. Hans-Dieter Barke, University of Muenster, GERMANY

© 2023 Federation of African Societies of Chemistry (FASC)

Enquiries and manuscripts should be addressed to the Editor-in-Chief: email eic@faschem.org, PO Box 2305, Addis Ababa, Ethiopia.

CONTENTS

EDITORIAL

1. OBITUARY TO PROF. JOHN BRADLEY 1
2. ACRICE-5 SUCCESSFULLY CONDUCTED 5

RESEARCH PAPERS

- A novel approach for the integration of organic extraction, green chemistry, and infrared spectroscopy concepts in undergraduate organic chemistry laboratory
Victoria Andre, Hiba Ahmad, and Khalique Ahmed 6
- Hidden persuaders in a systemic approach to learning about electrochemical cells and circuits
John Bradley and Peter Moodie 15
- Assessment of current chemistry laboratory status and practices of secondary schools in Finote Selam town
Derejaw Yesgat and Belete Asefa 29
- Which base needs to be used to deprotonate a given Bronsted acid? Quantitative approach
Bogdan Doboszewskia and Edmilson Clarindo de Siqueira 56
- Application of "three-step method" in calculation of conditional potential and precipitation solubility in analytical chemistry
Ruijia Lan, Li Cheng, Wenbin Su and Lin Qian 78
- Chemical composition analysis of palm oils in Ijebu-Ode, Ogun state
Samson Oluwasegun Aruna 91
- Analysis of content alignments between the new grade 7 general science textbook and the respective syllabus
Eshetu Desalegn Alemneh and Solomon Melesse Mengistie 112
- Phytochemistry of selected Gambian traditional medicinal plants
Alhagie Drammeh, Momodou K.A Sowe, Anthony Adjivon, Momodou Salieu Sowe 144
- Qualitative molecular orbital theory suited for the high school student
Rasmus Persson 162
- Assessment of status and practices of chemistry laboratory organization and utilization in 'Adet' and 'Debrenewii' secondary schools, Amhara Region, Ethiopia
Asefa Belete, Teshome Mulugeta, Mulugeta Teshome Gebreyes, and Asefa Belete 178
- REVIEWS**
- Feasibility of doing insightful final year projects in chemical sciences at home: concepts, themes, outcomes, challenges, resources, journals
K. Sivakumar 221
- Perspectives on general aspects of pollution toxicology
B.H.S. Thimmappa 240
- GUIDELINES FOR AUTHORS** 293

EDITORIAL

1. OBITUARY TO PROF. JOHN BRADLEY
2. ACRICE-5 SUCCESSFULLY CONDUCTED

AJCE Editorial Team
Email: eic@faschem.org

1. OBITUARY TO PROF. JOHN BRADLEY

MEMORIAM JOHN BRADLEY (1937-2022)



By Marissa Rollnick and Elizabeth Mavhunga (Taken from SACI website)

Professor John Bradley joined the Wits School of Chemistry in 1964 after completing his studies at the University of Leeds and the University of London (King's College) and his postdoctoral fellowship at Florida State University. He worked his way up the ranks and became a full professor. He spent 58 fruitful years at Wits in several capacities, all with the central theme of Chemical Education.

Early Period: Wits School of Chemistry, 1964 – 1990:

He began as a pure chemist, but through his contact with other colleagues who were concerned about the lack of conceptual learning in undergraduate courses, he began to explore better ways of teaching

chemistry. He was actively involved in curriculum development in both lecture and laboratory classes across the undergraduate spectrum (1st year general chemistry and 2nd- 4th year organic chemistry as well as 4th year science education. According to Gus Gerrans, in 1986 he introduced SGTs (Small Group Tutorials) in 1st year chemistry courses as part of what was called TLLM (Teaching Less and Learning More).

He was the driving force behind the creation of the Science Education Committee in the Faculty of Science together with notable academics in other disciplines and created Honours options in Science Education, offered primarily to teachers and teacher educators. This was followed by the creation of a Master's degree in Science Education. His concern about the poor throughput rate in the Faculty of Science led to the establishment in the late 1980s of a two-year bridging programme leading to second year BSc. This later evolved into the College of Science (a fully-fledged extended curriculum programme at Wits which ran from 1990-2004).

His mentoring approach to chemical education started with his colleagues, exemplified by the reflections of Dr Margie White, a former tutor (1981 – 2006) who reflected, “My approach to teaching changed drastically in that time.... input from John turned my understanding of chemical concepts and the teaching of them, upside down - start with the small (the microscopic) and then understand the large (macroscopic)”.

During this period, he was president of SACI (1988-1990), education officer of SACI (1992-2015) and Chairman of IUPAC committee for the teaching of chemistry.

RADMASTE (Research and Development in Mathematics, Science and Technology Education): 1990 – 2014

As his interest in Chemical Education grew, John felt the need for making a wider impact on the teaching and learning of chemistry in South Africa and later beyond. Together with colleagues in physics and mathematics, he established RADMASTE, an organisation that worked to improve the teaching of both teachers and teacher educators and began the work that led to international recognition – the development of microscale chemistry kits and accompanying materials, culminating in a NSTF award in 1998, an award from International Organization for Chemical Sciences in Development, and finally an international microscale chemistry award. A fellow microscale developer in the UK, Bob Worley reflects, “A giant in the microscale world has passed on. I was determined at the time in 1991, ... not to lose the well-known school experiment - the reduction of copper oxide by hydrogen. I found one (safe) method (developed) by John, ... which I adapted for use with equipment found in our school labs”.

An article by Beverley Bell, formerly of RADMASTE, provides evidence of Important work with Chemistry teachers in Africa (50 sites in 28 Countries), South and Central America and the Caribbean (7 countries), Europe and Eurasia (24 countries), Asia (10 countries), Indian Ocean Islands (4).

A former RADMASTE colleague and now lecturer in the Wits School of Education, Dr Mpunki Nakedi reflects, “to me John was not just a teacher, a leader or a colleague, but was like a father I feel I did not honour enough, and I am immensely grateful for that profound undeserved connection”.

Throughout his career, John found time to supervise postgraduate Students, amongst them, Professor Nthabiseng Ogude (PhD 1991), Professor Elizabeth Mavhunga (Masters with distinction in 1997), Dr Betty Dlamini (PhD 2000), Dr Sabelo Manyatsi (PhD 1997) and Dr Margie White (PhD 1997).

Dr Betty Dlamini reflected, “He will indeed be remembered for his sharp observations and his gentle comments while guiding the theses writing. You just never forget his insights to your ideas as a student”.

“Retirement”

John never really retired. RADMASTE moved to the Wits Education Campus in 2009, he taught chemistry courses for the honours programme in Science Education on an honorary basis from 2002 – 2018. Marissa Rollnick reflects, “I began to co-teach the course with him and gained a new insight into chemistry ideas, some so new that to understand his approach, I found it necessary to video record his classes, as what he was sharing was unavailable in any literature. In later years he began to provide “notes” which provided insight into his thinking on key topics such as ‘acids and bases’ and ‘atomic structure and bonding’”.

Peter Moodie, with a physics background, relearnt most of his chemistry from John and was struck by John’s ability to take a reader straight to key principles, often lost in textbooks. He writes, “I was relieved after struggling with bonding theory rules, to be reminded that bonding is simply electrostatic attraction between atoms. The physics was so obvious when he pointed out that big idea. But I wondered how many students do get lost in the labyrinth of chemical theory in various topics. John argued that these are mostly taught separately with no Big Ideas offered to create a whole picture.”

John Bradley made an invaluable contribution to future science teachers, teaching final year students chemistry up to November 2022. As Professor Elizabeth Mavhunga put it, “he persistently challenged us to think big, think contemporary and never be complacent about our teaching offerings”, a stimulus for her initiative to review the 4 years of the B.Ed., which she began in 2021 in

collaboration with Dr Emmanuel Mushayikwa. According to Peter Moodie, John submitted a paper to IUPAC just before he went on leave in December 2022. In this paper he elucidated much of his thinking about the future direction of initial teacher education in the context of climate change and social change.

Acknowledgements:

Dr Margie White (ex-Wits), Dr Batseba Mofolo-Mbokane (Wits), Prof Paddy Lynch (Tasmania), Mina and Prof Ben Staskun (ex-Wits, Australia), Prof Gus Gerrans (ex- Wits, USA), Prof Jorge Ibanez (Mexico City), Bob Worley (CLEAPSS, UK), Marietjie Potgieter (UP), Prof Supawan Tantayanon (Thailand), Prof Leslie Glasser (Ex- Wits, Australia), Dr Betty Dlamini (Eswatini), Dr Mpunki Nakedi (Wits), Beverley Bell (ex-RADMASTE), Dr Solomon Akinyemi (Wits), Dr Sinegugu Khulu (Wits) and Dr Belinda van der Westhuizen (Wits), Peter Moodie (Wits).

From AJCE

Prof. John Bradley

1. Has been serving as a member of the International Advisory Board of AJCE since its establishment in 2011.
2. Has been serving as anonymous reviewer of manuscripts submitted to AJCE.
3. Has published and co-published articles in AJCE.

We miss his professional support to AJCE. Let God bless his soul and give strength to his family.

2. ACRICE-5 SUCCESSFULLY CONDUCTED

ACRICE Editorial Team

eic@faschem.org

The 5th African Conference on Research In Chemical Education [ACRICE-5], hosted by Ain Shams University, Cairo, Egypt, was conducted on 7-9 December 2022 with a theme: **Teaching Chemistry for a sustainable future**. ACRICE-5 was endorsed by the Egyptian Academy of Scientific Research and Technology, International Union of Pure and Applied Chemistry (IUPAC), the Federation of African Societies of Chemistry [FASC], 10 Academy, Falconess.

The Conference was sponsored by IOP publishing (bronze), and Dragon Oil (gold). Praxi Labs (bronze), Taylor and Francis (bronze) and was put under the UN International Year of Basic Sciences. ACRICE-5 was followed by post conference workshop on STEM Education and 4th Industrial Revolution. The previous conferences were held in Ethiopia (Dec.2013), South Africa (Nov.2015), Algeria (Oct.2017), and Nigeria, (Sept.2019).

There were plenary, keynote, workshops and panel presentations given by eminent experts from the appropriate fields of research in Chemistry education from USA, UK, Canada, Germany, Sweden, Norway, Spain, Russia, China, Taiwan, Saudi Arabia, Dubai, South Africa, Kenya, Benin, and Egypt.

The Guest of Honor was Prof. Javier Garcia, IUPAC president who attend the conference and gave the opening and closing remarks. The Conference was held under the Patronage of Prof. Dr. Mahmoud El Metinie ASU president and Prof Dr. Ayman Saleh ASU vice president for graduate studies and research. Whereas Prof. Dr. Farouk Fahmy (ASU) served as the Conference Chair, Prof. Dr. Nadia Kandil. (ASU) was chair of the Scientific Committee. Prof. Dr. Ghada Bssioni. (ASU) served as Chair of the Organizing Committee.

FASC holds ACRICE every two years.

A NOVEL APPROACH FOR THE INTEGRATION OF ORGANIC EXTRACTION, GREEN CHEMISTRY, AND INFRARED SPECTROSCOPY CONCEPTS IN UNDERGRADUATE ORGANIC CHEMISTRY LABORATORY

Victoria Andre, Hiba Ahmad, and Khalique Ahmed*

Lynn University, College of Arts and Sciences, 3601 North Military Trail Boca Raton FL, 33431, USA

Corresponding Email: kahmed@lynn.edu

ABSTRACT

In almost all undergraduate organic chemistry laboratory curricula, students are taught the concepts of organic extraction and infrared spectroscopy through some appropriate experiments. In the case of organic extraction, a typical experiment, found in most organic chemistry laboratory manuals, involves the extraction of caffeine from tea. Furthermore, it is common for students to perform infrared spectroscopy in a separate experiment, allowing the student to gain a better understanding of the unique vibrations of distinct functional groups. In this short communication, we report the integration of these laboratory activities into a single activity, which teaches the concepts of green chemistry, organic extraction, and analytical infrared spectroscopy. [*African Journal of Chemical Education—AJCE 13(1), January 2023*]

INTRODUCTION

Caffeine is a naturally occurring substance in many plants. Examples include tea leaves (*Camellia sinensis*); coffee beans (*Coffea arabica*); cocoa (*Theobroma cacao*); shrub holly (*Ilex glabra*); tree holly (*Ilex cassine*); and guarana (*Paullinia cupana*) [1]. As an alkaloid, caffeine is both a stimulant and a diuretic. It can be consumed in over-the-counter drugs as well as various beverages including coffee, tea, cocoa, and many carbonated drinks.

Caffeine analysis is vital for quality and quantity control purposes. For instance, in order to meet regulatory standards, beverage industries must guarantee a certain maximum caffeine level in decaffeinated drinks [2].

Since there are many different natural products in caffeine-containing plants, the isolation of the desired compound, caffeine, can be achieved by techniques such as liquid-liquid extraction, high-pressure liquid chromatography (HPLC), and recrystallization. Such procedures require large quantities of toxic organic solvents, such as dichloromethane, and generate large quantities of organic hazardous waste [2, 3, 4]. This poses a health risk to the students in the lab setting and also has the potential of emitting toxic chemicals into the environment.

In this short communication, we demonstrate that attenuated total reflection infrared spectroscopy (ATR-IR) can be successfully utilized for the estimation of caffeine levels in tea. This technique is rapid, reagent-free, cost-effective and most importantly it does not produce any hazardous organic waste [6].

EXPERIMENTAL

The caffeine content of a dozen tea samples was investigated. As presented in Table 1, five of these were imported from Sri Lanka; six were purchased at a local grocery store in South Florida, however, originated in either China or Brazil; and one was obtained on the Lynn University campus.

Table 1. Names, types, and origins of the studied tea samples.

| Name | Type of tea | Origin |
|-------------|--------------|------------------------|
| Ruhunu | Black | Sri Lanka |
| Uva | Black | Sri Lanka |
| Dimbula | Black | Sri Lanka |
| Matale | Black | Sri Lanka |
| Nuwarheleya | Black | Sri Lanka |
| Ti Kuan Yin | Oolong | China |
| Gunpowder | Green | China |
| Jasmine | Green | China |
| Sow Mee | White tea | China |
| Mate | Holly Family | Brazil |
| Mate Leao | Holly Family | Brazil |
| Holly Tree | Holly Family | Lynn University Campus |

Each tea sample, in the amount of 5.0 grams, was boiled in 100 milliliters of water for 15 minutes, using a Cimarac 2 Thermolyne hotplate, and then allowed to cool to room temperature.

Thereafter, 5 microliters of the water extract were used for infrared spectroscopic measurements. The remaining water extract for each tea was transferred to a separatory funnel and 15 milliliters of dichloromethane was added to extract caffeine. Subsequently, the dichloromethane layer from the separatory funnel was transferred into a flask and the solvent was allowed to evaporate under a fume hood in order to obtain solid caffeine crystals. The caffeine crystals were then weighed to obtain the amount of caffeine in 5 grams of tea leaves. The purity of these caffeine crystals was analyzed by determining their melting points using Electrothermal, Mel-Temp® apparatus and 1.1-1.2 Id x 100mm melting point tubes.

Infrared spectroscopy analysis was performed using a vector 33 spectrometer from Bruker® (Billerica, MA). Infrared spectra were recorded in the attenuated total reflection (ATR) mode by using Miracle® single reflection attenuated total reflection cell from PIKE technologies (Madison, WI). Globar source, KBr beam splitter, open channel, and DTGS detector were utilized in the infrared measurements. All spectra were recorded at a 4-cm^{-1} resolution and 128 scans were averaged to obtain each spectrum.

The infrared calibration was established by utilizing the Quant1 method from Bruker®.

RESULTS AND DISCUSSION

The infrared spectra of pure water and caffeine water extract are shown in Figure 1. The major peaks in these spectra arise from OH stretching 3300 cm^{-1}) and OH bending (1640 cm^{-1})

vibrations. The two spectra appear identical as the infrared absorptions of the various functional groups of caffeine are very weak.

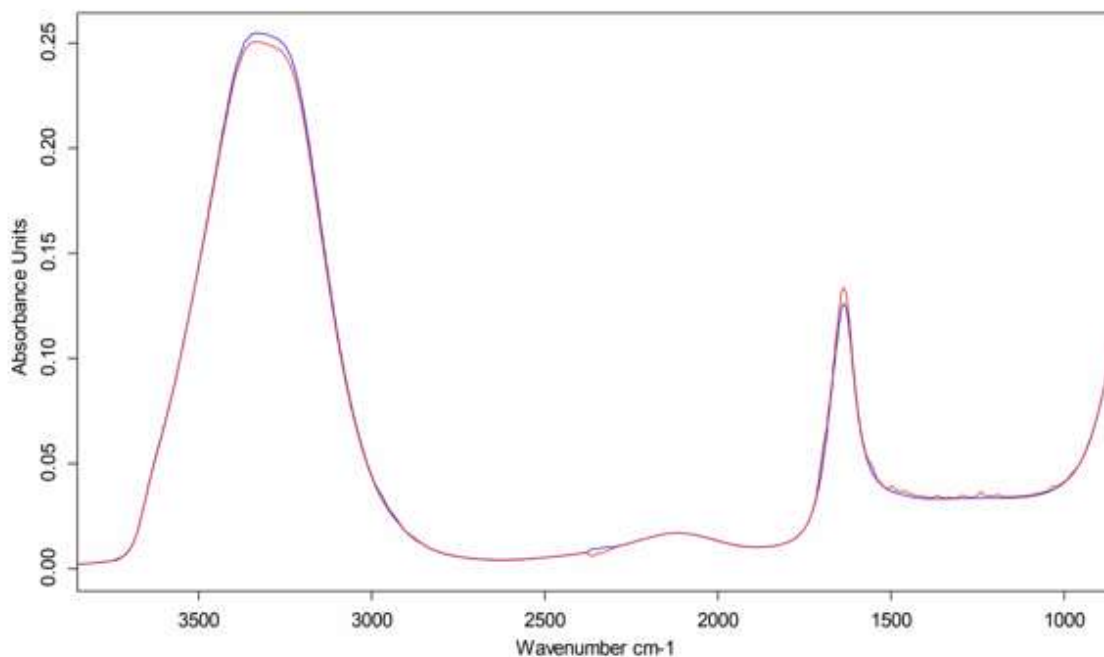


Figure 1: Comparison of the infrared spectra of five microliters samples of pure water and boiled tea in water in the region of 4000-900 wavenumbers.

Figure 2 displays an expansion of the 1550-1000 cm^{-1} region of the spectra of Figure 1, in order to view these caffeine infrared peaks. The identity of these caffeine peaks was confirmed through the measurement of the spectrum of pure commercial caffeine which is shown in Figure 3. The spectrum of pure caffeine has been overlaid by the spectrum of extracted caffeine to verify the success of the extraction with dichloromethane.

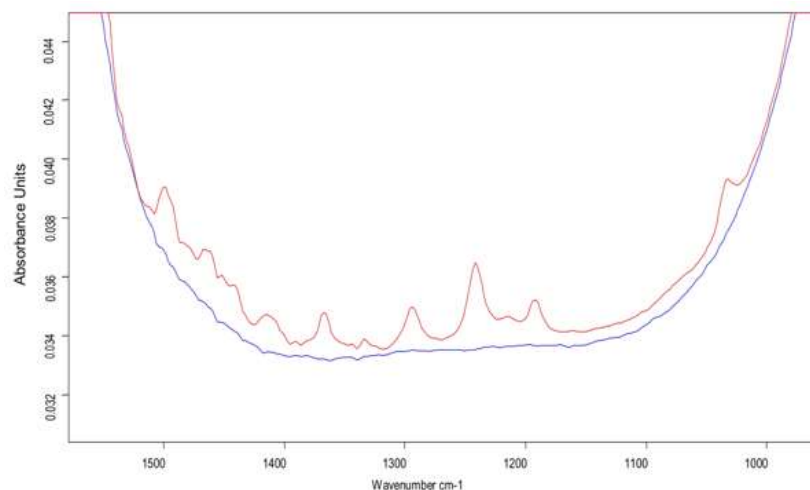


Figure 2: Comparison of the infrared spectra of pure water (lower spectrum) and boiled tea in water (upper spectrum) in the region of 1550-1000 wavenumbers.

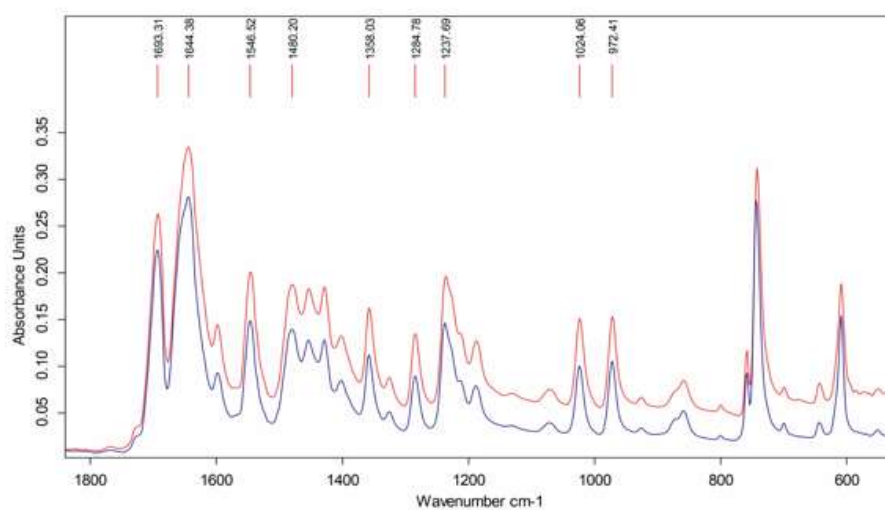


Figure 3: Comparison of Infrared spectra of extracted caffeine (lower spectrum) and commercial caffeine (upper spectrum) in the region of 1800-500 wavenumbers.

To obtain the calibration plot seven samples were randomly chosen from Table 1. The infrared spectra of caffeine water extract of the selected samples in the region of $1550\text{-}1000\text{ cm}^{-1}$ along with the associated caffeine values (mg/gram) determined through dichloromethane extraction were subjected to Bruker's Quant1 method. The resultant calibration plot is shown in Figure 4. The correlation coefficient of 0.98 indicated a nearly perfect linear relationship between the spectral features and caffeine content.

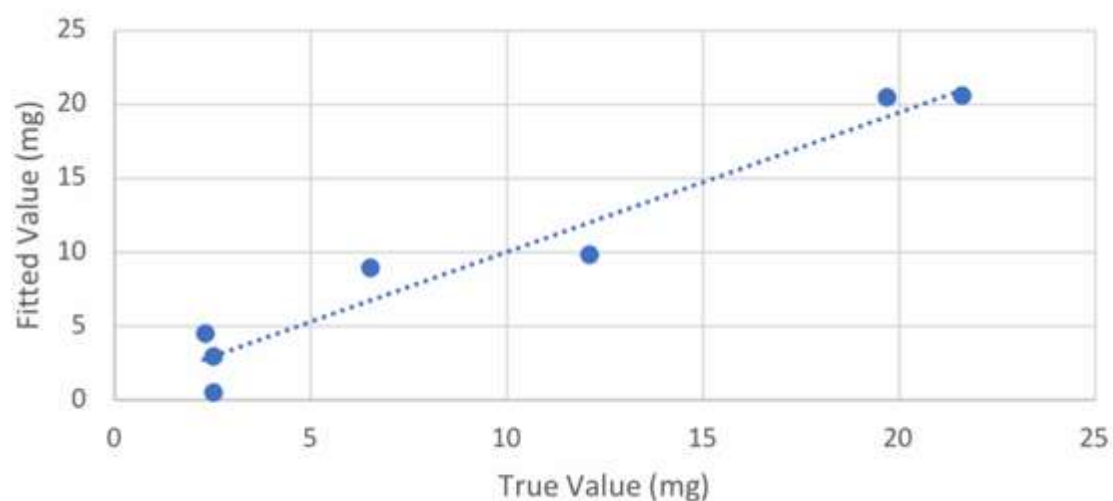


Figure 4: Infrared calibration plot for the caffeine content in representative tea samples.

The calibration of Figure 4 was used to predict the amount of caffeine in the five tea samples of Table 1 that were not used to establish the calibration. The data of Table 2 shows an excellent match between the actual and predicted caffeine values in the test samples.

Table 2: Prediction of Caffeine Content in Representative Tea Samples Based upon the Infrared Calibration.

| Test Sample | Actual Value (mg/g) | FT-IR Predicted Value (mg/g) |
|-------------|---------------------|------------------------------|
| Ruhunu | 6.70 | 6.50 |
| Sow Mee | 8.92 | 9.31 |
| Mate | 5.10 | 5.86 |
| Mate Leao | 14.20 | 13.74 |
| Holly Tree | 12.90 | 15.61 |

In summary, the caffeine content of tea samples can be successfully determined through infrared spectroscopy without the use of any organic solvent.

CONCLUSION

The study demonstrates that *attenuated total reflection infrared (ATR-IR) spectroscopy* can be successfully utilized for the estimation of caffeine content in tea [5]. Infrared methodology is

rapid and eliminates the use of organic solvents. The proposed methodology can be utilized to integrate the concepts of organic extraction, green chemistry, and infrared spectroscopy in the undergraduate level organic chemistry laboratory.

REFERENCES

1. Kato M, Mizuno K, Crozier A, Fujimura T, Ashihara H. Caffeine synthase gene from tea leaves. *Nature*. **2000** 406(6799):956-957. DOI:10.1038/35023072
2. Adam D.J.; Mainwaring J.; Quigley M. N. Extraction of Caffeine from Beverage Plants. *Journal of Chemical Education* **1996** 73 (12), 1171 DOI: 10.1021/ed073p1171
3. Janusz Pawliszyn, Min J. Yang, and Maureen L. Orton Quantitative Determination of Caffeine in beverages Using a Combined SPME-GC/MS Method. *Journal of Chemical Education* **1997** 74 (9), 1130 DOI: 10.1021/ed074p1130
4. Murray S. D.; Hansen P. J. The Extraction of Caffeine from Tea. *Journal of Chemical Education* **1995** 72 (9), 851 DOI: 10.1021/ed072p851
5. Schulz H, Engelhardt UH, Wegent A, Drews H, Lapczynski S. Application of near-infrared reflectance spectroscopy to the simultaneous prediction of alkaloids and phenolic substances in green tea leaves. *J Agric Food Chem*. **1999** 47(12):5064-5067. DOI:10.1021/jf9813743

HIDDEN PERSUADERS IN A SYSTEMIC APPROACH TO LEARNING ABOUT ELECTROCHEMICAL CELLS AND CIRCUITS

John Bradley and Peter Moodie
Wits School of Education, South Africa
Corresponding Author Email: Peter.Moodie@wits.ac.za

ABSTRACT

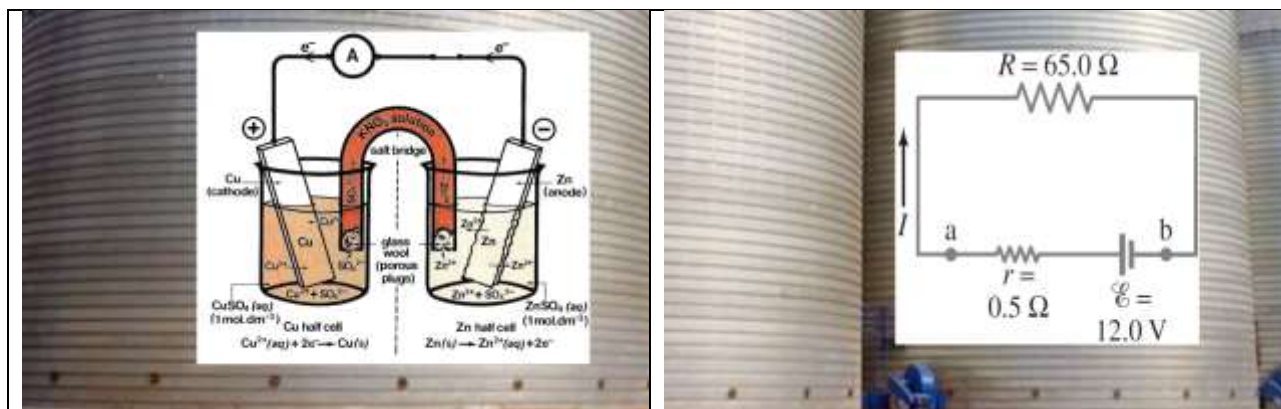
In this paper we discuss the meaning and language associated with use of the symbols + and - with particular reference to electrochemical cells and circuits. We propose that the undifferentiated use of plus and minus signs in that context creates possibilities for students to form misconceptions, and in this way the plus and minus signs are also “hidden persuaders”. We consider in turn the charges of ions, the meaning of oxidation numbers, the role and character of electrodes, and the nature of standard electrode potentials. [*African Journal of Chemical Education—AJCE 13(1), January 2023*]

INTRODUCTION

A recent paper [1] in this Journal is testimony to the continuing concern about the teaching and learning of electrochemistry. It is evident that there are several aspects needing attention and some of these may originate in the traditional separate teaching about cells (in chemistry) and about circuits (in physics). In a previous paper [2] we argued that a systemic approach to teaching and learning about electrical cells and circuits could help avoid misconceptions separately reported by physics and chemistry education researchers. Our thinking is that to some extent this problem derives from the existence of two curricular silos of knowledge and the teaching and learning about them, when in reality there is one system.

In a subsequent presentation [3] we illustrated the problem with the images on the right and below. In the chemistry silo, students are presented with the chemist's depiction of the reactions in a voltaic cell. The current is shown as a flow of electrons going anticlockwise. In the physics silo, the students meet a very different depiction of a cell, merely two vertical lines with an unexplained space between them. They also see a separate resistor labelled $r = 0.5 \, \Omega$ that indicates the cell's internal resistance. The current is clockwise around the circuit.





Given the siloed curricula found in many educational institutions, it is perhaps not surprising that students do not see a circuit as a single physico-chemical system in which, as with all systems, a change in one part has effects in all the rest of the system. It is this latter idea that is a foundation concept for systems-thinking.

We have considered what a systemic approach to electric cells and circuits would look like in practice. As we developed the approach, the complexity of a development which involves some degree of integration of the teaching of two separate disciplines became increasingly apparent. Amongst the aspects of basic importance is that of the language used. Here the word ‘language’ is meant to cover terminology, symbols and models. Differences between the ‘languages’ of the disciplines are a potential source of misconceptions, especially when learners study both physics and chemistry as separate disciplines. We suggest that the idea of ‘hidden persuaders’ introduced by Schmidt (1991) offers an appropriate framework for thinking about science concepts in a situation where the topic of study lies within two disciplines. This is the situation when cells and circuits are

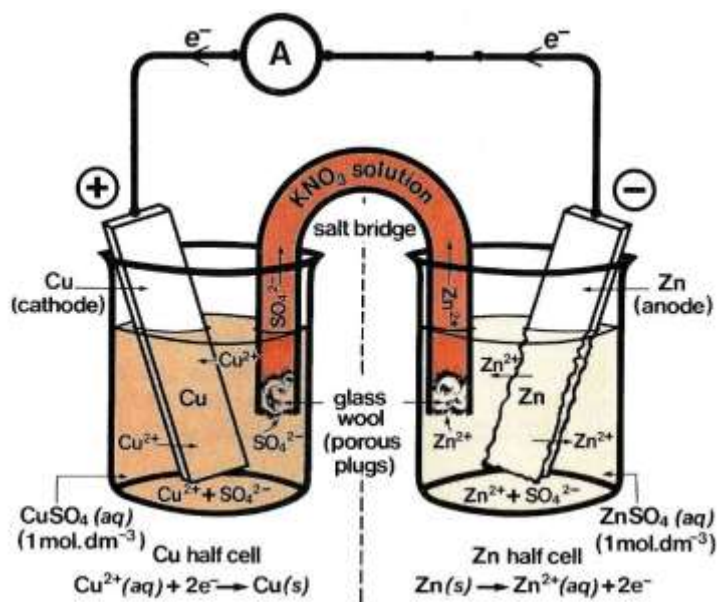
studied as a system. When not treated as a system but as made up of two silos (physics and chemistry), there will be opportunity for forming misconceptions due to ‘language’ differences.

Schmidt (1991) [4] introduced the description ‘hidden persuaders’ to draw attention to some misconceptions about acid-base reactions that can be traced to the use of the term neutralisation. This term (or label as he called it) has a long history of use in association with describing the characteristics of acids and bases (or alkalis). In a subsequent paper, he and Volke (2003) [5] reported on the alternative concepts of students and the historical shift of meaning of the term oxidation. These examples from two traditional chemistry topics alert us to the likelihood of other areas of chemistry where other hidden persuaders lead to misconceptions

In this paper we discuss the meaning and language associated with use of the symbols + and - with particular reference to electrochemical cells and circuits. We propose that the undifferentiated use of plus and minus signs in that context creates possibilities for students to form misconceptions, and in this way the plus and minus signs are also “hidden persuaders”. We consider in turn the charges of ions, the meaning of oxidation numbers, the role and character of electrodes, and the nature of standard electrode potentials.

We will begin by considering the diagram below; it and others like it are common in chemistry textbooks.

The diagram shows much sub-microscopic activity involving ions and electrons. The electrons are labelled with minus signs, the ions are labelled with plus or minus signs and the electrodes also have plus or minus signs next to them.



PLUS AND MINUS SYMBOLS AS HIDDEN PERSUADERS

In our previous paper [2] we listed 3 misconceptions each as reported from the two separate disciplines, one of which is the focus of this paper:

The + and – labels on the cell terminals represent the charges they bear. Inside the cell cations move towards the – electrode whilst anions move towards the + electrode. In electrolytic cells the signs are reversed.

It seems clear that the + and – labels on the cell terminals have been interpreted as indicators of charge in this quotation. We think that the + and – signs on electrodes, as used in cell diagrams, invite students to think in physics terms, by which they see charged ions being attracted to an oppositely-charged electrode. Garnett and Treagust [6] reported on how high school students tried to reason about ion movements inside a cell on the assumption that the anode had a negative charge and the cathode a positive charge. They were unsuccessful! We think this is probably another important example of what Schmidt described as a ‘hidden persuader’.

CHARGES OF IONS

The + and - symbols are used to represent the charge of an entity such as an ion or an electron. Examples of the former are Cl^- and NH_4^+ . (According to rules published by IUPAC [7a] the charge symbol is always placed in the upper-right position in the formula.) In polyatomic ions there may be indications of the principal atomic location of the charge, but otherwise the charge is assumed to ‘belong’ to all the atoms in an unspecified way. Multiple charges (multiples of the elementary charge) are catered for by use of numbers, as in SO_4^{2-} for example. These charges are recognised as a natural

result of atoms being composed of protons and electrons (and neutrons). Ions with a negative charge are called anions whilst those with a positive charge are called cations.

In chemical equations where charged particles are represented, charge conservation must be observed, that is the nett charges represented on each side of the equation must be equal.

OXIDATION NUMBERS

In the dominant model of redox reactions, these reactions are viewed as electron transfer reactions. When the reactions involve ions, it is rather easy to see these transfers in the formulae of the reaction equation. But ions are not a necessary type of participant, and then identifying whether electron transfer is involved or not may be difficult. Oxidation numbers help for this purpose, because, in effect a polar covalent molecule is viewed as ionic. For example, the molecule H_2O is viewed as $2\text{H}^+\text{O}^{2-}$ and therefore the formation of the water molecule from reaction between hydrogen and oxygen molecules (molecules which are not polar, and with pairs of equally-shared electrons) implies loss of electrons by H atoms and gain of electrons by O atoms and

therefore a redox reaction. In the water molecule the oxidation number of H atoms is +I and of O atoms is –II. The use of Roman numbers like +I and –II emphasises that these are not full ionic charges when writing their formulae as H^{+I} and O^{-II} . The water molecules are not ionic, and they do not dissociate into ions in aqueous mixtures to any appreciable extent ($K_w=10^{-14}\text{mol}^2\text{dm}^{-6}$) and dissociation does not result in oxide ions but hydroxide ions.

ELECTRODES IN CELLS AND CIRCUITS

The electrodes of a cell are the key players in electrochemical phenomena. For example, ions generally form or react at electrodes as an essential part of the functioning of the cell when it is part of an electrical circuit. Chemical equations may also be written showing electrons (e^-) as reactants or products of the electrode reaction.

The electrodes are referred to as cathode or anode: at the cathode electrons from the external circuit are transferred to ions or molecules in the surrounding electrolyte; at the anode electrons are transferred to the external circuit either by loss of hydrated cations from the electrode or by loss of electrons from ions or molecules in the surrounding electrolyte. When the electrodes are connected by a conducting wire, electrons enter the external circuit at the anode and leave the external circuit

at the cathode. Within the cell there is an oxidation half-reaction at the anode and a reduction half-reaction at the cathode. [7b]

Electrodes may also be shown with the + and – symbols and, in words, they may be referred to as positive and negative electrodes. The symbols frequently appear on cells used by the general public, and devices using the cells generally have a diagram directing the user which way round to place the ends of the cell with + and – symbols. Learners quite reasonably think the symbols may represent charges on the electrodes. These charges may then be invoked to explain ion migration inside the cell eg students may think that cations (having a + charge) move towards the electrode bearing a – sign. However, this is not correct: cations migrate towards the cathode, which is labelled with a + sign. More reasonable is explaining the observation that electrons (having a negative charge) in the external circuit move from the - electrode to the + electrode.

The truth is that the + and - electrode signs do not relate to an actual charge but to the model of conventional current in the external circuit. This is a current of positive charges, the opposite of reality as we now see it in a metallic conductor! Electrical circuit diagrams usually relate to this convention with the cell in a circuit often represented as:

+|I-

The left electrode is the source of the conventional positive current. In reality the left electrode is where electrons enter the cell to participate in the reduction half-reaction at the cathode.

In any case the whole process is driven by the potential difference between the two electrodes not by a charge difference between them: they do not have nett charges.

Unfortunately for many learners the + and - labels given to electrodes (as in the textbook example above) act as hidden persuaders of a misconception. They are easily misunderstood as nett charges, because electrochemical cell diagrams usually have many + and – signs scattered around and most of the time they do mean to describe charges. The only exception is the signs on the electrodes. These signs should be omitted from electrochemical cell diagrams when the diagrams support understanding of events inside the cell. But of course, the circuit cannot be ignored, and it is the conduit for electron transfer between the electrodes. However, teachers of the topic should refrain from including these hidden persuaders with the electrodes, until a focus on the external circuit is appropriate. From the viewpoint of the cell, the electrodes have names (cathode and anode) which can be linked with reduction and oxidation half-reactions respectively and with the ion movements in the electrolyte.

STANDARD ELECTRODE POTENTIALS

Although electrodes may have electric potentials these cannot be measured: two electrodes are required to make a cell. The cell has a potential difference between the two electrodes which can be measured with a voltmeter. It is the sum of an oxidation potential (E_{ox}) for the anode and a reduction potential (E_{red}) for the cathode, and is generally called the cell potential (E_{cell}). A standard

reference electrode (the standard hydrogen electrode (SHE)) has been assigned the potential of 0,00 V and the potentials of all other electrodes are measured as components of a cell in which one half is the SHE. Tables of these electrode potentials are normally given as standard reduction potentials, and some appear with positive values and some with negative values. Positive values identify reduction half-reactions that are energetically more favourable than reduction of hydrogen ions, whilst negative values imply reduction is less favourable than is the reduction of hydrogen ions.

Although reduction potentials may be listed, oxidation potentials may be derived easily since $E_{\text{red}} = -E_{\text{ox}}$.

The + and – signs of electrode potentials reflect the use of a zero of reference in comparing all the different possible electrodes. (The situation is analogous to the Celsius temperature scale.) In chemistry education such comparisons are important for linking with Periodic Table trends.

Although the reason why some standard reduction potentials are positive and some are negative is straightforward, we found that some student teachers were persuaded to explain them in terms of charges, for example, as:

'Anode is a negative electrode, meaning the most negative species from standard reduction potentials will be anode....Cathode is a positive electrode which is mostly positive species from standard reduction potentials.'

SYSTEMS-THINKING ABOUT CELLS AND CIRCUITS

The above remarks focus on the chemistry inside the cell, with superficial reference to the external circuit. An interdisciplinary approach to cells and circuits will recognise the physics concerns with the effect of internal resistance and its increase as more current is drawn from the cell as the resistance in the external circuit decreases. This effect is taught in physics classes but seldom explained in terms of the reactions and ion movement inside the cell. An interdisciplinary approach that includes the chemistry discussed above would enable a teacher to give a satisfactory explanation for the internal resistance effect, the heating of the cell as it produces current, the relationship between the maximum current and the physical size of the cell, the choice of materials in the cell, and the reasons for connecting cells in series or in parallel in batteries

We would argue that the teaching strategy employed needs to take into account hidden persuaders that originate in one discipline and may be a source of misunderstanding in another. Learning about systems-thinking needs to include provision for confronting this issue. In the context of Big Ideas *about* science [8] there are likely to be many instances which relate to:

‘Scientific explanations, theories and models are those that best fit the facts known at a particular time.’

We argue that the cells and circuits case brings to the surface a problem that has been acknowledged but not satisfactorily confronted. In the current South African national curriculum

(CAPS) [9] for example, there is advice for grade 10 teachers of the Electricity and Magnetism knowledge area regarding conventional current:

‘The direction of current in a circuit is from the positive end of the battery, through the circuit and back to the negative end of the battery. In the past, this was called conventional current to distinguish it from the electron flow. However, it is sufficient to call it the direction of the current and just mention that this is by convention.’

This advice is surely unhelpful after teaching in earlier grades has devoted time to describing the electron flow in an electric circuit and the energy transfer associated with this. It also does not prepare for the teaching about electrochemical cells in grade 12.

Equally concerning is the implicit encouragement to thinking that the cell has charges on its terminals. Use of the terms ‘positive’ and ‘negative’ should be avoided as they may strengthen the persuasive influence towards belief in charges on the terminals. The + and – signs may be referred to as “plus and minus” signs instead, a reference which may have less persuasive potential to lead to misconception. Teachers could use "plus" and "minus" simply as indicators of the correct way to install or connect a battery. A teacher might say “The red wire goes to the terminal with the plus sign and the black wire goes to the terminal with the minus sign”.

It is better rather to heed the conclusion (30 years ago!) of Garnett and Treagust [10]:

“teachers, curriculum developers, and textbook writers, if they are to minimize potential misconceptions, need to be cognizant of the relationship between physics and chemistry teaching...”

REFERENCES

1. Ali, MT, Woldu, AR, and Yohannes, AG (2022). High school students' learning difficulties in electrochemistry: a mini-review. *African Journal of Chemical Education*, 12(2), 202- 237.
2. Bradley, JD and Moodie, P (2021a). A systemic approach to teaching and learning about electrical cells and circuits using two big ideas of science. *African Journal of Chemical Education*, 11(1), 1-14.
3. Bradley, JD and Moodie, P (2021b). Systems-thinking Microscale – Cells and Circuits. Presentation online at 11th International Symposium on Microscale Chemistry (ISMC), 14 July, UK.
4. Schmidt, H-J (1991). A label as a hidden persuader. *International Journal of Science Education* 13, 459-471.
5. Schmidt, H-J and Volke, D (2003). Shift of meaning and students' alternative concepts. *International Journal of Science Education* 25(11), 1409-1424.
6. Garnett, PJ and Treagust, DF (1992). Conceptual difficulties experienced by some high school students of electrochemistry: Electrochemical (galvanic) and electrolytic cells. *J. Research in Science Teaching*, 29, 1079-1099.
7. IUPAC (2007). *Green Book: Quantities, Units and Symbols in Physical Chemistry*, 3rd edition. (a) pp 49-53, (b) 70-76.
8. Harlen, W (ed) (2010). *Principles and Big Ideas of Science Education*. Hatfield: Association for Science Education.
9. Department of Basic Education (2011). *Curriculum and Assessment Policy Statement (CAPS): Physical Sciences FET Phase – Grades 10-12*. Pretoria: Government Printing Works.
10. Garnett, PJ and Treagust, DF (1992). Conceptual difficulties experienced by senior high school students of electrochemistry: Electric circuits and oxidation-reduction equations. *J. Research in Science Teaching*, 29, 121-142.

ASSESSMENT OF CURRENT CHEMISTRY LABORATORY STATUS AND PRACTICES OF SECONDARY SCHOOLS IN FINOTE SELAM TOWN

Derejaw Yesgat¹ and Belete Asefa²

¹Ph.D Candidate in Chemistry Education, Bahir Dar University, Bahir Dar, Ethiopia

²Department of Chemistry, College of Natural Science, Bahir Dar University, Ethiopia

Corresponding Author Email: yesgatderejaw@gmail.com

ABSTRACT

This research paper aimed to assess the practice, facilities, and effectiveness of practical work in Damot secondary school. The research was designed to narrate laboratory facilities (equipment and chemicals) and laboratory practice of Damot secondary schools and effectiveness of laboratory activities incorporated in grade twelve chemistry textbooks. Qualitative research method with thematic narration design were used to assess laboratory equipment availability and laboratory practice in Damot secondary schools and effectiveness of laboratory tasks incorporated in grade twelve chemistry textbook. In this study qualitative research approach was used to collect the relevant data. Qualitative data was collected through deep interpretive analysis of observed data, data from document analysis and data from the focus group discussion and data from the check list also used to examine meanings, themes and patterns of the laboratory task incorporated in the textbook during content analysis. Damot secondary school was moderately equipped in physical facilities, chemicals, equipment and other inputs. But the teachers who taught there have poor performance in implementing experimental works in laboratory. The assessment method, absence of specified laboratory technician, time allotment etc. make teachers, students, and administrators to highly focused in the theoretical aspect of the subject not on the practical aspect of the subject. Due to time allotment, class size and absence of laboratory technician teachers were forced to show laboratory activities in the form of demonstration instead of students practice on the task. Teachers lack commitment/interest and even skill to conduct laboratory activities in the laboratory. In addition, school administrator never supervises, organizes, and facilitates teachers and students to conduct experimental works there. [*African Journal of Chemical Education—AJCE 13(1), January 2023*]

INTRODUCTION

Background of the Study

Science education is frequently perceived to be of great importance because of its links to technology and industry, hence at national perspective may be areas with high priority for development. Consequently, science is included as a core element in elementary and secondary levels despite conceptual complexity and high cost of implementation. Another justification for the inclusion of science in school curricula is that all citizens need to achieve a degree of “scientific literacy” to enable them to participate effectively as citizens in modern societies. Chemistry, as an upper-secondary school subject, should aim to supply students with chemical literacy and chemical culture, to cultivate higher-order cognitive skills (critical thinking, problem solving, evaluative thinking and decision making) [1], and to be a useful, interesting, and enjoyable subject. As [2], chemical literacy may be practical or functional literacy which refers to the ability of a person to function normally in his/her daily life as a consumer of chemical and technological products, such as food, health, and shelter. Civic literacy refers to the ability of a person to participate wisely in a social debate concerning chemical and technologically related issues. Finally, cultural or ideal literacy refers to appreciation of the chemical endeavor, and the perception of science as a major intellectual activity.

Studying chemistry provides students not only with specific concepts and theories in chemistry, but also with tools, confidence and attitudes for constructing their future prosperous

society. Besides learning to think effectively and efficiently, students come to understand how chemistry deals with daily and routine lives of theirs and theirs and people at large. Students are also expected to realize the changing power of chemistry and its significance nationally as well as internationally.

Practical work has been defined as an experiment performed by the teacher and students for demonstrations, or series of experiments and observational exercises carried out by the students to relate theoretical knowledge with practical activities done in the laboratory, classroom, field or elsewhere [3].

The use of laboratory method of teaching science has become a dogma among science educators and teachers. On the one hand, they extolled the importance of the use of the laboratory method in science teaching while on the other hand, they only pay "lip service" to its use in practice. Science teachers do not usually find it convenient to make laboratory work as the center of their instruction. They usually complain on lack of availability of facilities like laboratory room, equipment, apparatus, and chemicals available to conduct experiments. they also complain on the time allotment, large class size, weekly working load, and curriculum design to carry out practical work. At the same time, it is possible that some of these materials and equipment may be locked up in the school laboratory store without teachers being aware of their existence. The conditions under which many teachers' functions do not engender any enthusiasm to use the laboratory method of teaching science even where they know that these materials and equipment are available.

As [4] described most of secondary as well as preparatory schools in Ethiopia and other countries in the world faced different problems that can hinder performing experiments and any practical activities as practical works in chemistry in particular and in science in general. Preparatory Science laboratory need to fulfill supplies, equipment and reagents. These facilities for science laboratory are paramount important for continuous and enormous range of experimentation, adjustment of apparatus, demonstration and laboratory equipment and supplies for on-going projects. It also requires enough space for storage and supplies as well as adequate electrical & water services, library resources like laboratory manuals, suitable demonstration desks, good ventilation and arrangement of the room.

As [5] described “laboratory conducted by students has long been considered the hallmark, the unique feature of science education. Science students should be taught for at least part of the time in the laboratory classes, students laboratory work is the method of choice for teaching technical skills and increasing understanding of the apparatus involved. Students’ laboratory work can also be effective in teaching application of scientific knowledge and principles.”

As most scholars in the field explained that the efficiency of practical work in science teaching is impaired not only by a critical shortage of well-trained science teachers but also by a variety of other factors such as: Insufficient laboratory facilities, lack of skilled laboratory technicians, the over loaded laboratory time tables, lack of time in some schools, too large class size for practical work.

As [4] revealed practical work can't be taken place without having the necessary equipment, apparatus and reagents in the school laboratory. Because of this student will have few or no exposure to practical activities and that is why they become confused, how to conduct practical activities and operating equipment as a college and university student when they completed preparatory or secondary school and have joined universities and colleges. Therefore, lack of materials and other facilities highly restrict students to perform practical works in the laboratory and demonstrations and other practical activities in the classroom or in the field.

As [6] declared that when the curriculum is designed depending on the education policy of the country, especially for science subjects, practical works like experiments, investigations, and demonstrations are included in the syllabus of each subject and grade level in order to achieve the desired goals of the subjects. MOE proposed that the expense of providing laboratories and equipment is a fundamental constraint on effective science teaching and the emphasis on the new science teaching programs on practical work for students has manifested this challenge for the developing countries.

As [4] explained, it is assumed that number of students per class should be limited and manageable by the teacher in order to follow and check up every activity that the teacher teaches and disseminates to the students. This becomes more essential for science teaching and to carry out practical activities as planned by the teacher when the number of students per class is manageable. So, to make effective demonstration in the class and carrying out experiments in the laboratory the

students must be grouped in small number and the chance of each student to involve in the practical activity will be high and the students will gain more exposure and experience sharing. On the other hand, as the number of students increases the opportunity of each student to participate in the group becomes low.

As [4] described

“the assessment strategies practiced in the school play a great role in enhancing the practical work performed in science courses. Practical examinations are one of the main factors influencing, the importance to which experimentation is put in science teaching. Technique, attention and accuracy, lay out of results, estimation of error and above all, ‘getting the right answer’ were the factors commonly rated in the making of candidates’ work of practical examinations. Without an examination a serious neglect of practical work can occur.”

Statement of the Problem

Regarding the importance of laboratory work in natural science, [2] has compared as “a fish can’t survive without water and likewise teaching science that does not support with practical activities is incomplete and science students are not fully trained.” So, learning by doing can be achieved only by conducting experiments.

Higher institutions in Nigeria charged with the responsibility of training science teachers at all levels, are increasingly turning out teachers without requisite laboratory experience. A common reason usually given is shortage of laboratory facilities. Such trained science teachers usually lack the necessary confidence to conduct practical classes with their students. It is only accreditation exercises that are improving this situation in Colleges of Education and Universities at present. Practical activities are essential in all levels of science education and in particular it is highly significant in senior secondary schools to help students in internalizing and understanding the theoretical knowledge of science fields such as Chemistry, Biology and Physics. The natural science core subject at the secondary level (grades 9-10) becomes distinctly differentiated as Biology, Chemistry and Physics.

According to [7] the cause of mass failure of students in secondary school chemistry examination includes teacher's methodology, structuring of the curriculum, the concentration of examination questions on few topics and the inability of the students to perform enough practical before their examination. Practical work is an inquiry and hands on activity which makes it possible to transfer knowledge on higher order cognitive levels and create curiosity in students' mind. But in reality, in different schools due to different reasons teachers are teach chemistry, simply using usual presentations method as a chemistry teaching method.

According to [8] foundation "if students are given a chance and ample time, they can design and modify their own experiment, meeting challenges as well as fruitful results, try things out with

a careful eye and ready mind as any professional scientists do. They need this personal experience for that they need time and encouragement, but not too much detailed orders and instructions or precautions, since they need to feel that it is their own experiment and to learn by their mistakes as well as their success.”

There should be a regular and effective implementation of practical work in senior secondary schools to bring science teaching at a standard level with better understanding and greater achievement of students. However, degree of implementation of practical activities and availability of laboratory equipment, availability of physical facilities, availability chemicals etc are differed from school to school.

As one of the authors was at Finote Selam teacher's college before, the author got an opportunity to deal with chemistry subject teachers and with school principals, on how can conduct a chemistry laboratory activity as the level or standard expected and one of the author observed and assess the real situation of chemistry laboratory practice in Damot secondary school. And even though laboratory has been given a central and distinctive role in science education, there is no study conducted on the assessment chemistry laboratory status and practices of secondary schools in Finote selam Town. These serious issues initiate the author to conduct this research.

Research Questions

This research has been guided by the following research questions.

1. Are there sufficient facilities for carrying out chemistry practical works in Damot secondary school?
2. Is there sufficient laboratory practice in Damot secondary school?
3. Are laboratory tasks incorporated in grade twelve chemistry textbook are relevance?
4. What is the effectiveness of laboratory activities incorporated in grade twelve chemistry textbook?

Objective of the Study

The specific objectives of the research were:

1. To assess the status of laboratory facilities in Damot secondary school
2. To assess status of laboratory practice in Damot secondary school
3. To assess the relevancy of laboratory tasks incorporated in grade twelve chemistry textbook
4. To assess the effectiveness of laboratory tasks incorporated in to grade twelve chemistry textbook.

Significance of the Research

This research is significant in:

- Providing insight for policy makers, developers, and school administrators about the status of their school basic laboratory facilities.
- Providing insight for policy makers, developers, school administrators and teachers about the status of implementation of practical activities.
- Inspiring teachers, policy makers, developers & students to aware the relevance of laboratory tasks.
- Providing insight for policy makers, developers, teachers and students about the effectiveness of grade twelve laboratory tasks.

METHODOLOGY OF THE RESEARCH

This study aimed at assessing laboratory facilities (equipment and chemicals) and laboratory practice of Damot secondary schools, relevancy and effectiveness of laboratory activities incorporated in grade twelve chemistry textbooks. With this in mind, this section encompasses the methodological aspects such as research design, the research method, sample and sampling procedure, data gathering instruments, data collection and data analysis technique of the study.

Research Design

The research was designed to narrate laboratory facilities (equipment and chemicals) and laboratory practice of Damot secondary schools, relevancy and effectiveness of laboratory activities incorporated in grade twelve chemistry textbooks. Qualitative research method with thematic narration design were used to assess laboratory equipment availability and laboratory practice in Damot secondary schools and relevancy and effectiveness of laboratory tasks incorporated in grade twelve chemistry textbook.

Research Method

In this study qualitative research approach (method) was used to collect the relevant data. qualitative data was collected through deep interpretive analysis of observed data, data from document analysis and data from the focus group discussion and data from the check list also used to examine meanings, themes and patterns of the laboratory task incorporated in the textbook during content analysis.

Sampling Techniques

The population of the study was all-natural science students, all chemistry teachers and all demonstrative staffs. in those selected schools.

To assess the current laboratory practice & laboratory status of secondary schools (9-12), Past discussion opportunity about the issue while I was at college and thinking as grade twelve is the last preparatory level for higher education entrance, make me to select Damot secondary schools in general and grade twelve chemistry in particular purposefully.

Among 8 chemistry teachers, as one teacher was a zone animator and since he was responsible to the laboratory, to get relevant data he was selected as a data source using purposive sampling method. besides, all three administrative leaders were selected using comprehensive sampling method and three students were selected randomly. A total of four sample were used as a data source.

Data Collection Instruments

To assess the practice and laboratory status in Damot secondary school and to answer the intended research questions; observation, focus group discussions and document analysis were used as data collecting instruments. And to assess relevancy and effectiveness of laboratory tasks incorporated in grade twelve chemistry textbook and to answer the basic research questions; data find from incorporated laboratory tasks using content analysis was used. Further to assess the effectiveness of laboratory tasks incorporated in grade twelve chemistry textbook, all fourteen laboratory tasks were assessed and checked through a chick list. The standard chick list that used to assess the effectiveness of grade twelve chemistry lab tasks were adopted from [9]

Data Analysis Technique

As the research follows a qualitative research approach, qualitative data analysis techniques were employed. To assess the practice and laboratory status in Damot secondary school and to answer the intended research questions, data collected through observation, focus group discussions and document analysis data collecting instruments, and to assess relevancy and effectiveness of laboratory tasks incorporated in grade twelve chemistry textbook and to answer the basic research questions collected qualitative data were analyzed using thematic narrative analysis technique.

ANALYSIS AND INTERPRETATION OF RESULTS

The data obtained from observation, focus group discussion and document analysis was used to answer the research question through the following briefed listed questions.

To assess the availability of facilities in Damot secondary school, the following points (physical facilities; availability of chemicals & reagents; laboratory apparatus and instruments) were considered; from observation and focus group discussion, the following findings were formulated.

Physical Facilities: laboratory room, electric system in laboratory room, water system in laboratory room, is isolated bench to each student during laboratory activities, black a white board etc. at Damot secondary school, there is a chemistry laboratory room which function for around 2000 (33 section) students. In each section there is about 60 students, and it is too much crowded to conduct

laboratory in the laboratory room. Besides the floor and windows are old enough, broken and scratched. Chemicals and reagents, apparatus, benches, and all in the laboratory rooms are exposed to dust and even for rain. As we know a laboratory room should be partitioned at least in to three room (chemical and apparatus store, preparation room and demonstration room) in line with this, the laboratory room in Damot secondary school was partitioned in to three parts-stores, demonstration room and chemical preparatory/pre demonstration rooms. Even if it is on and off there is a water and electric installation in the laboratory room. The problem here was, both water and electrical installation were not grounded, and it is not comfortable to the student during laboratory work even it is risk.

Another physical facility that the researchers interested was the presence of isolated bench in the laboratory. There are around 50 isolated new and standard benches around the laboratory table in the laboratory room, which is easy to move and manageable size. There is also white and blackboards in the laboratory room.

Availability of chemicals and reagents: There are some chemicals in the store, most of them are outdated. As the focal chemistry laboratory teacher most of laboratory activities were failed during the experiment but they are positive when they used chemicals from Finote Selam teachers' college. This is true even for chemicals that they get recently, and they feel un thrust on the distributer and the respected education sectors. The problem here is most teachers were refused and unable to

prepare solution with different concentration through dilution and other method. Chemicals in the laboratory room was tried to logically arrange using their properties. But the arrangements of chemicals were not that much fruitful due to the absence of responsible laboratory technician; teacher return chemicals after their experiments to improper position and due to insufficient shelf and partitioned class chemicals can be misplaced.

Laboratory apparatus and instruments: From the observation, and according to the focal person, most of instruments like thermometers, electronics beam balances, triple beam balance are not functioned. There are different sized and shaped test tube, beakers, measuring cylinders, long glassed tubes. Generally, laboratory apparatus in Damot secondary schools was sufficient but the problems here were a lot of test tubes, beakers, flasks etc were permanently contaminated with previous laboratory chemicals. Most teachers lack skill to prepare different sized and shaped glass tube. Most of long sized delivery tubes were finding as it were packed for a long period of time.

According to the school director and laboratory focal person, there is sacristy of chemicals and apparatus in the laboratory and most teachers lacked laboratory skill and they fright chemicals even. So, they advised higher institutions in general and chemistry departments in particular to

- Train students to perform laboratory activities, to arrange chemicals in logical order, to prepare chemicals from existing stock, and to prepare apparatus independently.

- Train teachers (short or long term) to perform laboratory activities, to arrange chemicals in logical order, to prepare chemicals from existing stock, and to prepare apparatus independently.
- To visit their laboratory activity and their laboratory room.

The types of laboratory experimentation commonly carried out in Damot secondary school as the laboratory focal person and from the researchers' observation were categorized under demonstration type. Most of the time after introducing the objective and theoretical aspect the daily laboratory activity, teacher showed laboratory activities for students practically. Sometimes the demonstration may be done by active students or group leaders. Even if there were procedure in the textbook, teachers tell and guide demonstrator students or group leaders to follow him and students in the group (8-10 students) observe what the group leader do. This is due to the crowdedness of laboratory room, unavailability of chemical, shortage of time (40 min and net less than 30').

In Damot secondary school, for each grade level, chemistry teachers prepared manual standing from students' textbook and regional animator chemistry manual. The existing manual was prepared by considering the existing school laboratory situation. Some laboratory activities were left from the textbook due to unavailability chemicals and apparatus in their laboratory and some other laboratory activities are added as a laboratory activity which are not yet designed in the textbook. The developed laboratory manuals incorporate more detailed and well-organized tasks. the beginning of the manual contains marking system (5% attendance, 15% laboratory report=20%),

submission date (submission date is always when student came to the next laboratory). As the animator and from researcher observation, even if most students (7-8 students) were not actively involved in the experiment few students were actively participated in the laboratory activity. They effectively follow the procedure on their manual, they weigh, they measure, they register their data and observation etc. and those students frequently call their teacher when they fell ambiguity.

Most of the chemicals and apparatus they used during their laboratory work are pre-determined and collected to the table by their teacher before students entered to their laboratory. Throughout their laboratory work teachers assist and guide students and, in some occasion, teacher allow active group students to demonstrate their laboratory works for other groups. As from students' laboratory report, some teachers marked student's laboratory reports and wrote constructive comments on their report.

As the animator, due to time scarcity and class size teachers have not got chance to assess or marke students higher thinking order cognitive, affective and psychomotor domains. The only assessment method that held by the teacher were assessing and marking of students group laboratory report. So, laboratory report was the only chance of the teacher to assesses his/her students. This laboratory report assessment mostly classified under lower cognitive assessment, besides the problem here was laboratory reports are only done by group leaders or even worst by other body. Mostly laboratory tasks that need higher order cognitive (applications, analysis and evaluation), affective and psychomotor, like setup construction, preparation of solution, preparation of apparatus

are not allowed to the students to perform during their laboratory activities. Students' performance of the above types was not assessed by the teacher due to large size of students in a group and in the class and the time given to assess made those assessment to sub pressed. Even if teachers sometimes try to observe how students follow the procedure that they follow, teachers have no time to assess them.

According to the laboratory focal person, among nine chemistry teachers only three of them are interested in conducting laboratory with their students frequently but others six of them were not well in helping their students through conducting laboratory activities. And he concludes that as there was no separate time allotment for laboratory session, they have no extra time to conduct laboratory activities but most of them are good at theoretical teaching in their class.

In grade twelve old chemistry curriculums, there are 14 laboratory activities and chemistry teachers added other relevant chemistry laboratory activities standing on the manual developed by Amhara regional chemistry animators' group. But the total laboratory activities planned by Amhara regional laboratory animator for preparatory and secondary school were 21 laboratory activities. Those laboratory manuals are also in hand of each group representatives. From old grade twelve chemistry text, all the procedure and instructions were written for the students. But since most of grade twelve students or high school students are not skilled enough in in processing practical laboratories and to avoid risks in some cases teachers should be share some tasks specially at procedure which leads risk. As one of the researchers assessed, there is no phrase which allow

teachers to help their students. Even if the procedure lacks teacher involvement and teacher role, the procedure and instructions are written in a clear and concise forms.

From the observation and information given by the laboratory focal person there are some experiments which are proposed in grade twelve chemistry curriculum but no chemicals in Damot preparatory and secondary school to conduct the experiments. For instance, under experiment 1.2, investigating properties of some mixture, gentian violet and real bile, experiment 2.1, the buffer action of solution, PH meter as apparatus, experiment 6.1, synthesis of nylon, hexamethyl diamine and adipoyl chloride chemicals are not available in Damot preparatory and secondary school. Teachers were forced to ignore those experiment.

The relevance of listed laboratory activities was assessed by relating them to the topic that they are intended to. As our assessment, under experiment 1.5, preparation of solution of known concentration, students are asked to weigh 11.7 g of NaCl and mix it with 50 g of water, here there is no more clarity or checkup mechanism weather it is the intended concentration or not. This is not relevant to the topic instead it is relevant to skill of measuring masses. In experiment 1.6, preparation of solution of lower concentration from stock solution, students are allowed to carefully add 10ml of stock sulfuric acid to 50 ml of distilled water and asked them to calculate the new concentration and to justify weather there is a change in number of moles of the original and final solution. Here from the experiment, students have no chance to understand about the number of moles of the two

solutions without calculation. So, this experiment is not relevant, it is better to use animation or simulation to justify about number of moles of the two solutions.

As all know there is no separate time allotment for chemistry laboratory activities. As Ethiopian educational curriculum there are four period allotment per week with forty min duration. To your surprise these durations are totally addressed to the theoretical learning objectives. Then there is no time allotment for the laboratory sections and most teachers used one period for their laboratory task and some other teachers used their free time in opposite shift. The problem here is the laboratory room also busy at opposite shift. Then teachers are forced to use their period for laboratory activity. As most of chemistry teachers and focal person students wastes at least ten min to come and go to the laboratory room and they left only thirty min in the laboratory. This thirty min is not enough even for demonstration. And teachers are complaining to have a consecutive (80 min) in a week. Under experiment 1.2, investigating properties of some mixture, the procedure order students to wait the mixture for 30 min and under experiment 6.1, synthesis of nylon, students are allowed to follow six procedures and each procedure are asked them to measure chemicals. Those two experiments are long enough and cannot completed in a period.

According to [9] effectiveness of laboratory work can be assessed by considering the match between what students are intended to do in the task and what they actually do; and between what students are intended to learn from the task and what they actually learn. By determining the effectiveness of a lab task, it is also important to determine which aspects of the task design leads to

its effectiveness or non-effectiveness. To evaluate the effectiveness of grade twelve chemistry laboratory tasks, all fourteen laboratory tasks were assessed and checked through a chick list. The standard chick list that used to analyze the effectiveness of grade twelve chemistry lab tasks was adopted from [9].

The checklist describes the following aspects of the laboratory task:

A: The intended learning outcomes (learning objectives);

B: Key elements of the task design, including:

B1: the cognitive structure of the task

B2: the level and nature of student involvement

B3: the practical context of the task.

Some of those aspects of laboratory tasks can be sub categorized in to specific type of aspects that can be addressed to a specific laboratory task.

Learning objectives may be factual, or they may be higher order process type, and both of them were assessed.

Table 1: Aspect A: Intended learning objectives

| To help students to... | | Tick one or more boxes |
|------------------------|--|------------------------|
| Content | Identify objectives & became familiar with them | |
| | Learn a fact | x |
| | Learn a concept | |
| | Learn a relationship | x |
| | Learn a theory | x |
| Process | Learn how to use a standard lab. Apparatus/instruments | x |
| | Learn how to carry out a standard procedure | x |
| | Learn how to plan an investigation to address a specific problem | x |
| | Learn how to process data | x |
| | Learn how to use data to support conclusion | x |
| | Learn how to communicate the result of lab work. | x |

All laboratory tasks incorporated in each grade level secondary school chemistry curriculums were intended the students perform laboratory activities using the procedure designed in the textbook. And students are intended to answer the questions and to observe phenomena while they perform their lab, to record their observation and data, and to write reports using their data.

Table 2: Aspect B1: The cognitive structure of the task

| B1. 1: What students are intended to do with objectives and observables? Tick one or more boxes | | |
|---|--|------------------------|
| Use | An observation or measuring instrument | x |
| | A laboratory device or arrangements | x |
| | A laboratory procedure | x |
| Present or display | An object | |
| Make | An object | |
| | A material | x |
| | An event occurs | x |
| Observe | An object | x |
| | A material | x |
| | An event | x |
| | A physical quantity | x |
| B1.2: what students are intended to do with ideas | | tick one or more boxes |
| Report observations | | x |
| Identify a pattern | | x |
| Explore r/b | Objectives | x |
| | Physical quantities | x |

| | | |
|--|-------------------------------|---------------------|
| | Objects & physical quantities | x |
| Discover a new concept (a physical quantity) | | |
| Determine the value of a physical quantity (not measured directly) | | x |
| Test a prediction | From a guess | |
| | From a law | x |
| | From a theory | x |
| Accounts for observation | in terms of a given law | x |
| | By proposing a law | |
| | By proposing a theory | |
| Choose b/n two or more given explanations | | |
| B1.3: objectives-or ideas-driven? | | Tick one box |
| What the students are intended to do with ideas arise from what they are intended to do with objectives | | x |
| What the students are intended to do with objectives arises from what they are intended to do with ideas | | |
| There is no clear r/s b/n what the students are intended to do with objectives and with ideas | | |

Grade twelve students are intended to use objects and observables in observation or measuring instrument as

- ✓ A laboratory device or arrangements
- ✓ A laboratory procedure
- ✓ Present or display an object like setup to make a material (chemicals) and events like indicators.
- ✓ Students intended to observe and make object, materials and events also they intended to observe physical quantities and to determine it which is not measured directly.
- ✓ But the text suppressed invention and discovery of concepts.

Table 3: Aspect B2: level and nature of student involvement

For B2.1: 1, =specified by teachers, 2=decided by discussion 3=chosen by students

| B2.1: Degree of openness/closure write 1, 2, and 3 | |
|--|---|
| Question to be addressed | 1 |
| Equipment to be used | 1 |
| Procedure to be followed | 1 |
| Method of handling data collected | 1 |
| Interpretation of results | 3 |
| B2.2: Nature of student involvement tick one box | |
| Demonstrated by teacher; students observe | |
| Demonstrated by teacher; students observe and assist as directed | |
| Carried out by students in small group | x |
| Carried out by individual students | |

As assessed, grade twelve chemistry textbook laboratory tasks incorporated in the text strict allowed students in the activity. But question to be addressed, equipment to be used, procedure to be followed were selected by teachers, and only interpretation of data was done by students and the laboratory activities were more intended to be done by small group. This type of laboratory activities was categorized under guided type enquiry.

Table 4: Aspect B3: The Practical Context

| B.1: Duration of task | | Tick one box |
|--|--|-------------------------------|
| Very short (Less than 20 min) | | |
| Short (say, up to 80 min) | | x |
| Medium (2-3 science lessons) | | |
| Long (2 weeks or more) | | |
| B3.2: people with whom the student interacts | | tick one or more boxes |
| Other students carrying out the same lab work | | x |
| Other students who have already completed the task | | x |
| Teacher | | x |
| More advanced students (demonstrators, etc) | | x |
| Others (technician, glassblower, etc) | | |
| B3. 3: information sources available to the student | | tick one or more boxes |
| Guiding worksheet | | |
| Textbook | | x |
| Handbook (data book) | | x |
| Computerized database | | |
| Other | | |
| B3.4: types of apparatus involved | | tick one box |
| Standard lab equipment | | x |
| Standard lab equipment + inference to computer | | |
| Every day equipment | | |
| B3.5: source of data | | tick one box |
| Real world: inside lab | | x |
| Real world: outside lab | | |
| Simulation on computer | | |
| Video recording | | |
| Text | | |
| B3.6: tool available for processing data | | tick one or more boxes |
| Manual calculation | | x |
| computer | | |

Under practical context in high school chemistry curriculum students were allowed to perform lab activity in 40 min. in small group at maximum, but in reality, students have no chance to use even 30 min., this is because during curriculum development time of laboratory activities were not considered. The laboratory procedure also clearly designed but the subject of each task was not defined. Due to the absence of a lab technician in high school teachers and active/model students can demonstrate some laboratory demonstrations. during their lab textbooks and handbooks are their information sources and standard/purchased lab equipment are used their lab activity. Phenomena inside lab were students' data source and those data are allowed to process using manual calculations.

CONCLUSIONS

Based on major findings, the following conclusions were drawn:

- ❖ Damot secondary school was moderately equipped in physical facilities, chemicals, equipment, and other inputs. But the teachers who taught there have poor performance in implementing experimental works in laboratory.
- ❖ The assessment method, absence of specified laboratory technician, time allotment etc. make teachers, students, and administrators to highly focused in the theoretical aspect of the subject, not on the practical aspect of the subject

- ❖ The schoolteachers were not interested to use their knowledge, experiences, and good opportunities to work many practical works and brings teaching chemistry more tangible, attractive, and easy for their students.
- ❖ Due to time allotment, class size and absence of laboratory technician teachers were forced to show laboratory activities in the form of demonstration instead of students practice on the task.
- ❖ Teachers lack commitment/interest and even skill to conduct laboratory activities in the laboratory.
- ❖ In addition, school administrator never supervises, organizes and facilitates teachers and students to conduct experimental works there.

REFERENCES

1. Tsaparlis, G., & Zoller, U. (2003). Evaluation of higher vs. lower-order cognitive skills-type examinations in chemistry: implications for university in-class assessment and examinations. *University Chemistry Education*, 7(2), 50-57.
2. Shwartz, Y., Ben-Zvi, R., & Hofstein, A. (2006). The use of scientific literacy taxonomy for assessing the development of chemical literacy among high-school students. *Chemistry Education Research and Practice*, 7(4), 203-225.
3. Reid, N., & Shah, I. (2007). The role of laboratory work in university chemistry. *Chemistry Education Research and Practice*, 8(2), 172-185.
4. Zengele, A. G., & Alemayehu, B. (2016). The Status of Secondary School Science Laboratory Activities for Quality Education in Case of Wolaita Zone, Southern Ethiopia. *Journal of Education and Practice*, 7(31), 1-11.
5. Chin, C., & Brown, D. E. (2002). Student-generated questions: A meaningful aspect of learning in science. *International Journal of Science Education*, 24(5), 521-549.
6. Al-Najar, N. (2016). View of education development in Oman. *International Journal of Academic Research in Education and Review*, 4(1), 10-18.

7. Akinola, B. M. A. (2006). Causes of mass failure in senior secondary school chemistry in Ijebu East Local Government Area of Ogun State. *Oro Science Educational Journal*, 4, 19-24.
8. Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (Vol. 13). London: The Nuffield Foundation.
9. Millar, R., Tiberghien, A., & Maréchal, J. F. L. (2002). Varieties of labwork: A way of profiling labwork tasks. In *Teaching and learning in the science laboratory* (pp. 9-20). Springer, Dordrecht.

ACKNOWLEDGMENT

We would like to thank Mr. Bekalu Molla for his unlimited and continuous supply of laboratory room data.

WHICH BASE NEEDS TO BE USED TO DEPROTONATE A GIVEN BRONSTED ACID? QUANTITATIVE APPROACH

Bogdan Doboszewski^{a*} and Edmilson Clarindo de Siqueira^b

^aDepartamento de Química, Universidade Federal Rural de Pernambuco,
52171-900 Recife, PE, Brasil

^bLaboratório de Bioprocessos, Centro de Tecnologias Estratégicas do Nordeste, 50740-540 Recife,
PE, Brazil

*Corresponding Author Email: bogdan.doboszewski@ufrpe.br

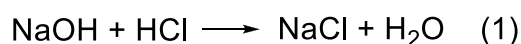
ABSTRACT

A simple quantitative evaluation of the positions of equilibria for the acid-base reactions is presented with emphasis on the organic chemistry. The method is applied for deprotonation of Bronsted C-H, N-H and O-H acids. [*African Journal of Chemical Education—AJCE 13(1), January 2023*]

DEPROTONATION OF BRONSTED ACIDS

Deprotonation of Bronsted acids is a frequent operation to get anions (or nucleophiles). Considering a range of the pKas of the acids, a practical question arises which base is capable to deprotonate a given acid and to what extent. Surprisingly, this issue is not treated quantitatively in the organic chemistry textbooks with sufficient attention and the thermodynamic criteria are not presented to answer this question.

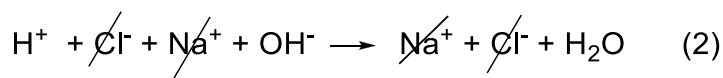
Let's take a trivial example of primary school chemistry:



and let's ask why this reaction occurs from a thermodynamic standpoint and why this reaction is written as going from the left to the right only, and if it is exergonic or endergonic? To answer this one must use a version of the fundamental Gibbs equation:

$$\Delta G^{\circ} = -1.36 \log K$$

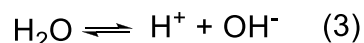
If $\log K > 0$, or positive, then $\Delta G^{\circ} < 0$, or negative, so the free energy content of the products is smaller than that of the substrates and the reaction is exergonic and spontaneous and goes as written from the left to the right. How can one evaluate the ΔG° of the reaction (1)? To do this, it is necessary to re-write the reaction (1) as shown below.



Since both Cl^{-} and Na^{+} are present on both sides of the equation, they can be cancelled and

$$K = \frac{[H_2O]}{[H^+][OH^-]}$$

The numerical value of K can be easily evaluated since it is a reciprocal value of the known dissociation constant of water K' (reaction 3):



$$K' = \frac{[H^+][OH^-]}{[H_2O]} \quad pK_a \sim 16; \quad K' = 10^{-16}$$

and thus,

$$K = \frac{1}{K'} = 10^{16}$$

Since the K of the reaction (1) is big and positive, the associated Gibbs free energy is highly negative.

$$\Delta G^0 = -1.36 (\log 10^{16}) = -21.7 \text{ kcal/mol}$$

As a conclusion, the reaction (1) is exergonic and goes to the right as written.

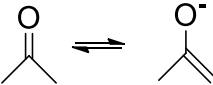

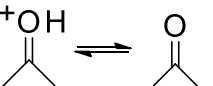

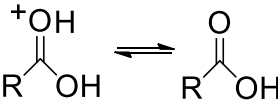
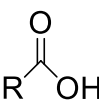



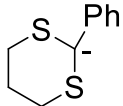
The same reasoning can be extended to the organic substrates. A purpose of the present didactic text is to apply this thinking to the other acid-base reactions and to show how to choose a necessary strength of a base to deprotonate a given acid and to calculate the equilibrium constant. Attention will be given to the Bronsted acids.

The following acids/bases will be used throughout this text and their associated pKas values are shown in the Table 1.[1,2] Besides the reference 1 and 2, the internet data bases can be consulted.[3] The pKas presented in these references vary slightly, but are consistent. It should be pointed out that evaluation of the strength of very strong acids with negative pKas varies contingent upon a method of evaluation and consequently, their pKas should be treated only as approximate

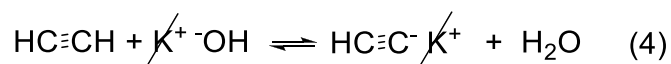
values. For instance, protonation of diethyl ether furnishes the conjugated Bronsted acid which has pKa between -0.30 and -6.2.[1] Likewise, protonation of the carbonyl group of acetone furnishes the conjugated acid which has its pKa between -0.24 and -7.2.[4,5] The same uncertainty about the pKas applies to very weak acids.

It should be pointed out that the dissociations shown in the Table 1 represent strictly speaking the processes in a gas phase, because no bases are shown to pick up the liberated proton. The dissociations in gas phases are highly endergonic since the charges are separated without any solvation, as shown by the theoretical calculations.[6]. Nevertheless, such treatments of the behavior of the acids are very convenient and represent a kind of the “half-reactions”, the other half is a binding of a proton by the conjugated base of the other acid. This will be shown below in details.

Table 1. A list of the pKas of acids

| | pKa |
|---|-------|
| $\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$ | 9 |
| $\text{Et}_3\text{NH}^+ \rightleftharpoons \text{Et}_3\text{N} + \text{H}^+$ | 10.7 |
| $\text{NH}_3 \rightleftharpoons \text{NH}_2^- + \text{H}^+$ | 32 |
| $i\text{Pr}_2\text{NH} \rightleftharpoons i\text{Pr}_2\text{N}^- + \text{H}^+$ | 36 |
| $\text{H}_2\text{O} \rightleftharpoons \text{HO}^- + \text{H}^+$ | ~16 |
| $\text{H}_3\text{O}^+ \rightleftharpoons \text{H}_2\text{O} + \text{H}^+$ | -1.7 |
| $\text{R}\overset{+}{\text{O}}\text{H} \rightleftharpoons \text{ROH} + \text{H}^+$ | -2.5 |
| $\text{PhOH} \rightleftharpoons \text{PhO}^- + \text{H}^+$ | 10 |
|  \rightleftharpoons  $+ \text{H}^+$ | 19.2 |
|  \rightleftharpoons  $+ \text{H}^+$ | -5 |
| $\text{R}-\text{CH}=\text{O} \rightleftharpoons \text{R}-\text{CH}=\text{O}^- + \text{H}^+$ | 16-17 |
|  \rightleftharpoons  $+ \text{H}^+$ | -6 |
| $\text{RCO}_2\text{H} \rightleftharpoons \text{RCO}_2^- + \text{H}^+$ | ~5 |
| $\text{CH}_4 \rightleftharpoons \text{H}_3\text{C}^- + \text{H}^+$ | ~50 |
| $\text{Bu-H} \rightleftharpoons \text{Bu}^- + \text{H}^+$ | ~50 |
| $\text{HC}\equiv\text{CH} \rightleftharpoons \text{HC}\equiv\text{C}^- + \text{H}^+$ | 25 |
| $\text{H}_2\text{C}=\text{CH}_2 \rightleftharpoons \text{H}_2\text{C}=\text{CH}^- + \text{H}^+$ | 44 |
|  \rightleftharpoons  $+ \text{H}^+$ | 43 |
|  \rightleftharpoons  $+ \text{H}^+$ | 30 |
| $\text{Cl}_3\text{CH} \rightleftharpoons \text{Cl}_3\text{H}^- + \text{H}^+$ | 15.5 |
| $\text{H}_2 \rightleftharpoons \text{H}^- + \text{H}^+$ | 35 |

A problem to solve is which base is able to remove a proton from a given acid and what is the equilibrium constant and the associated Gibbs free energy. Let's consider a reaction (4), attempted deprotonation of acetylene using KOH.



As in the reaction (1) the potassium cations can be cancelled since they are present on both sites of the equation, and the equilibrium constant has a form (5).

$$K = \frac{[\text{HC}\equiv\text{C}^-][\text{H}_2\text{O}]}{[\text{HC}\equiv\text{CH}][\text{OH}^-]} \quad (5)$$

To evaluate it quantitatively, one has to apply a trick of multiplication by $1 = [\text{H}^+]/[\text{H}^+]$ and to re-write it as follow.

$$K = K \cdot 1 = K \frac{[\text{H}^+]}{[\text{H}^+]} = \frac{[\text{HC}\equiv\text{C}^-][\text{H}^+]}{[\text{HC}\equiv\text{CH}]} \frac{[\text{H}_2\text{O}]}{[\text{H}^+][\text{OH}^-]} = 10^{-9} \quad (6)$$

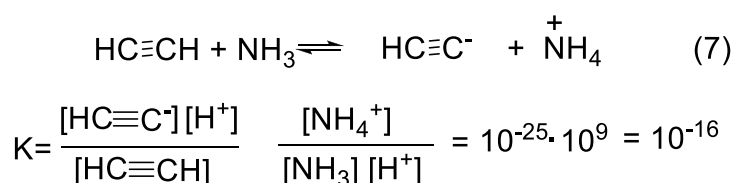
\swarrow dissociation constant of acetylene, $\text{pK}_a=25$, $K=10^{-25}$ \searrow association of H^+ and OH^- , $K=10^{16}$

$$\Delta G^\circ = -1.36(-9) = 12.2 \text{ kca/mol}$$

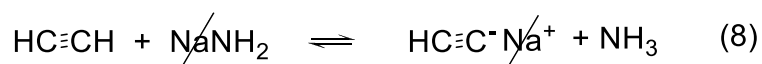
The association of H^+ and OH^- has been already treated in the reaction (1) and (2). We can see that the overall equilibrium constant of the reaction (6) can be easily derived from two “half-reactions” shown in the Table 1, and that it is very small, and its logarithm is negative. Consequently, the Gibbs free energy is positive, and the process does not advance to the right. At equilibrium there will be much more acetylene and KOH than the acetylide anion and water. KOH is definitely not

strong enough to remove a proton from acetylene. A reaction in the opposite direction is in fact favored, which is deprotonation of water molecule by the acetylide anion, and it has an equilibrium constant of 10^9 .

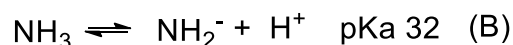
Attempted deprotonation of acetylene by commonly used bases like ammonia or triethylamine, which are approximately of the same strength, is also unsuccessful as shown below (reaction 7).



For triethylamine the same equilibrium constant would be $10^{-14.3}$, very small indeed. As a conclusion, both ammonia and triethylamine are also too weak to deprotonate acetylene appreciably. Evidently a stronger base is needed to get acetylide. Let's use sodium amide, NaNH_2 , where a basic part is NH_2^- , a conjugated base of ammonia, which is a very weak acid, so NH_2^- is a very strong base (reaction 8).



One must not confuse two processes (A) and (B) shown below.



The process (A) depicts acidic properties of the ammonium cation and indicates, that its conjugated base, ammonia, is a moderately strong base, whereas the process (B) shows ammonia as a very weak acid, which implies that its conjugated base is very strong. We will use exactly the last base in an attempt to get acetylide anion.

The equilibrium constant for the reaction (8) has a form of (9):

$$K = \frac{[\text{HC}\equiv\text{C}^{\cdot-}][\text{NH}_3]}{[\text{HC}\equiv\text{CH}][\text{NH}_2^{\cdot-}]} \quad (9)$$

After multiplication by $[\text{H}^+]/[\text{H}^+]$ we get (10) which can be evaluated quantitatively using the “half-reactions” from the Table 1.

$$K = \frac{[\text{HC}\equiv\text{C}^{\cdot-}] [\text{H}^+]}{[\text{HC}\equiv\text{CH}]} \times \frac{[\text{NH}_3]}{[\text{H}^+] [\cdot\text{NH}_2]} = 10^{-25} 10^{32} = 10^7 \quad (10)$$

↓ ↓

dissociation, $K=10^{-25}$ association, $K=10^{32}$

One can now evaluate of the Gibbs free energy:

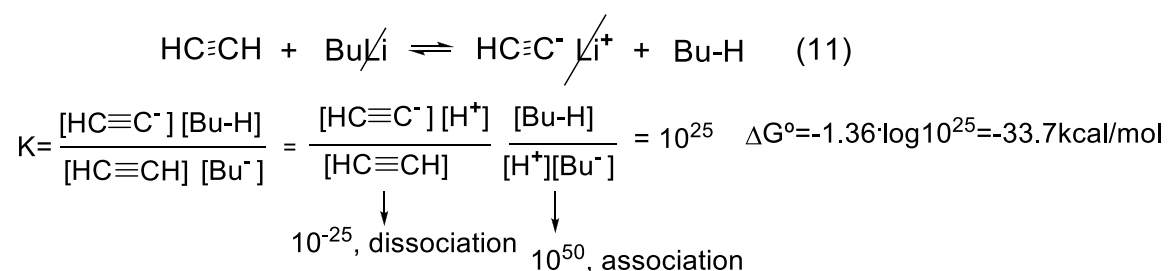
$$\Delta G^{\circ} = -1.36 \cdot \log 10^7 = -10.5 \text{ kcal/mol}$$

The process (8) is exergonic and proceeds to the right. High numerical value of K means that the reaction (8) is for practical reasons irreversible and quantitative.

As a conclusion, sodium amide is a base adequately strong to deprotonate acetylene and this process is exergonic.

The same sort of evaluation can be performed using the other bases like methyl lithium, MeLi and butyllithium, BuLi. Both are the strongest bases in use since the hydrocarbons are the weakest acids known. The basic part of both reagents is an anion R^- , a conjugated base of hydrocarbons (methane or butane; $pK_{as} \approx 50$), without any stabilization of the negative charge, which is localized on the carbon atom. The factors which control acidity are presented in any organic textbook. Briefly, the electronegativity, the polarizability and the stabilization by resonance are essential to stabilize the negative charge of a conjugated base after departure of a proton.

The equation (11) represents deprotonation of acetylene by butyllithium.



The process depicted in the equation (11) has very big equilibrium constant and is practically quantitative, irreversible and highly exergonic. The other strong bases like PhLi, MeLi, *t*BuLi or *i*Pr₂NLi (LDA), etc. can also be used for this purpose. It can be seen that the alkyllithiums are excellent bases for deprotonations in general.

A generalization can be made already at this point. During any acid-base reaction there is always an acid-substrate (which we want to deprotonate) and an acid-product, a conjugated acid of a base used for deprotonation. If a given reaction is supposed to go from the left to the right and be

exergonic, the acid-product must be weaker than the acid-substrate. To say this in the other words, the base-product must be weaker than the base-substrate. This is seen in the reaction (11): the acid-product (butane) is weaker than the acid-substrate, acetylene, so the process goes as written. Obviously, the base-product, acetylide, is weaker than the base-substrate, Bu^- . The opposed can be seen in the reactions (4) and (7). In (4) the acid-product (water, $\text{pK}_a \sim 16$) is stronger than the acid-substrate (acetylene, $\text{pK}_a 25$) and the reaction is endergonic and does not go to the right. Likewise, in (7) the acid-product (NH_4^+) is stronger than the acid-substrate, acetylene, and the base-product (acetylide) is stronger than the base-substrate (ammonia). For this reason, the reaction (7) does not progress to the right since it is endergonic. For practical reasons it is enough to compare the strengths of both participating acids only since their pK_a s are tabulated, whereas the strengths of the bases must be inferred from the strengths of their conjugated acids which is less convenient.

The other strong base used in a common practice is lithium diisopropylamide or LDA. This reagent can be prepared by deprotonation of diisopropylamine (reaction 12) which is very weak acid (pK_a ca 36), so very strong base (BuLi or MeLi) is needed. The calculations which show that such reaction functions well and that the associated equilibrium constant is big, are shown below.



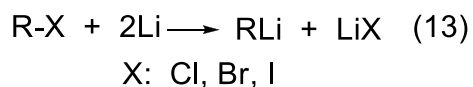
$$K = \frac{[i\text{Pr}_2\text{N}^-][\text{H}^+]}{[i\text{Pr}_2\text{NH}]} \cdot \frac{[\text{Bu-H}]}{[\text{Bu}^-][\text{H}^+]} = 10^{14}$$

\downarrow
 dissociation
 $K=10^{-36}$

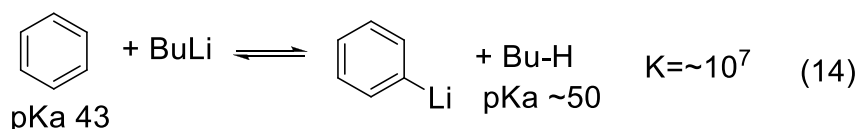
\downarrow
 association
 $K=10^{50}$

Considering a fact that CH_4 and butane have approximately the same pK_a s (~ 50), methyl lithium can be a replacement in the reaction (12).

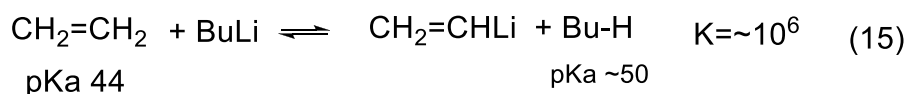
To get the LDA though, one must have the bases like BuLi or MeLi. Both cannot be prepared by direct deprotonation of methane or butane, since there are no bases strong enough for this purpose, so indirect approach must be used, which is a metalation (reaction 13).



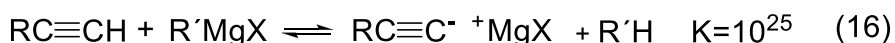
In this way the strongest bases known can be prepared. Since the C-Li bonds are partially covalent, one can increase their ionic character and consequently the strength of the alkyl lithiums by addition of 1,2-tetramethylethylenediamine (TMEDA) or 1,2-dimethoxyethane. Both of these compounds form strong complexes with lithium cation and increase a strength of the anion as a base by increasing its distance between Li and the anionic C center. Also, the organolithiums tend to become monomeric after such treatment, which additionally increases their basic properties. This is illustrated by deprotonation of benzene by BuLi (reaction 14) with and without addition of TMEDA.



Even though the reaction (14) should go to the right as evidenced by a favorable equilibrium constant, the yield the phenyllithium is small (ca 5%), but increases to 76% after addition of TMEDA (ref. [2], p.723). Obviously, phenyllithium can be prepared by metalation of phenyl halides. Likewise, direct obtention of vinylolithium by deprotonation of ethylene by BuLi or MeLi should be possible as shown in the reaction (15). However, this reaction would be complicated by the anionic polymerization initiated by addition of BuLi to ethylene.[7] The methods to obtain vinylolithium are presented in the reference [8].

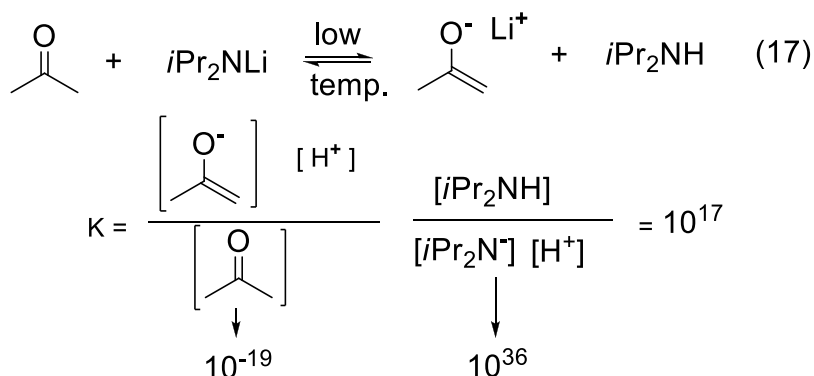


It should be pointed out that the Grignard reagents are also basic and capable to react with the Bronsted acids. Nevertheless, due to higher electronegativity of Mg (1.31, vs. Li, 0.98, Pauling scale), the C-MgX bonds are less polarized and more covalent than the C-Li bonds, and consequently, the Grignard reagents are less basic than the corresponding alkylolithiums. Nevertheless, the RMgX can be used interchangeably with RLi in certain cases as shown in the reaction 16.

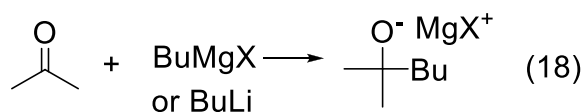


To perform the evaluation of K of the reaction (16) it was assumed that the RMgX is as strong as the RLi which obviously contradicts a statement above. In general, exact evaluation of the strength of the very weak acids is subjected to experimental errors, so quantitative differentiation of the strength of their conjugated bases neutralized by different cations is difficult, and in the first approximation it was assumed that both RLi and RMgX are of the same strength. At this point it should be mentioned that the Gilman reagents, R_2CuLi , are less basic than RMgX and RLi due to the electronegativity of the copper (1.9 in the Pauling scale). This means that the C-Cu bonds are weakly polarized and with little anionic character. The same applies to the other organometallics like R_2Cd and R_2Zn (electronegativity of both is ca 1.7).

Additionally, a distinction must be made between the nucleophilic bases and the non-nucleophilic bases. This can be illustrated by obtention of the enolate derived from acetone ($\text{pK}_a \sim 19$). As presented above, any conjugated base of the acid which has its $\text{pK}_a > 19$ will do the job, for example the LDA (pK_a of $i\text{Pr}_2\text{NH}$ is 36) as shown in the reaction (17). It can be seen that the LDA is sufficiently strong to deprotonate a molecule of acetone to form its enolate and that this process is practically quantitative and irreversible.

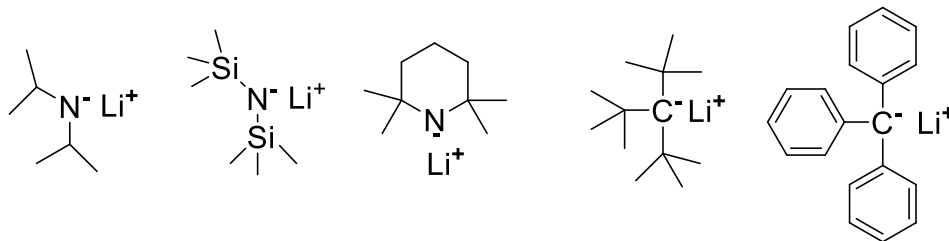


If BuMgX or BuLi were used for the same purpose, the outcome would be different as shown in the reaction (18).



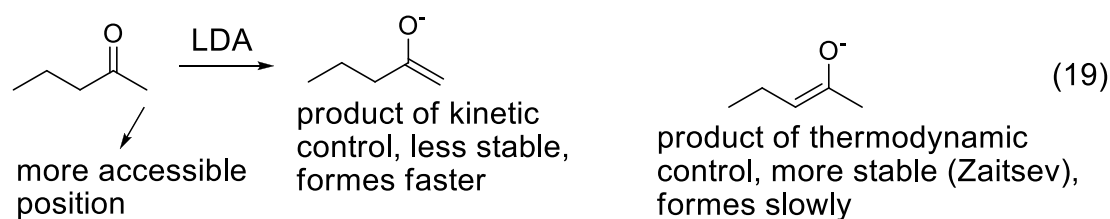
The main process would be the addition to the carbonyl group and a reduction of a carbonyl group by the hydride anion coming from BuMgX (ref [2], p.714) omitted for clarity. The deprotonation would not occur. This is an illustration of the nucleophilic character of the bases. The pair of electrons present in a given base can be used to remove a proton from a molecule (basic property) or can be transferred to a carbon atom (nucleophilic property). The addition to the carbonyl group is much faster than deprotonation, so both BuMgBr and BuLi behave like nucleophiles in the reaction (18). They are nucleophilic bases. At the same time, both BuLi and BuMgX do not add to the terminal carbon-carbon triple bonds, so the outcome of the reaction (11) and (16) is the same and deprotonation only takes place. If a steric bulk of the R group in the organometallics increases, like

in Ph_3CLi or $(\text{CH}_3)_3\text{CLi}$, the resulting compounds are unable to approach the carbonyl groups and to form the C-C bond. It is much easier for them to abstract a proton and to act as a base only, so they behave like non-nucleophilic bases. In general, the non-nucleophilic bases are sterically crowded and remove protons from the more accessible positions which permits to achieve regioselectivity. The structures of frequently used non-nucleophilic bases are shown below.

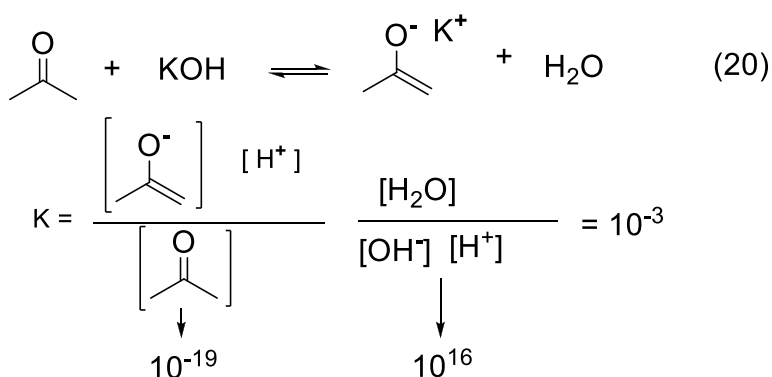


The non-nucleophilic base can be small however, like in the case of the sodium hydride, NaH . Its basic moiety is H^- , a very small anion, which is practically free of the nucleophilic properties. For this reason, NaH will deprotonate enolizable ketones or aldehydes to form the enolates, without addition to the carbonyl groups.

Let's return to deprotonation of ketones. As shown in the reaction (17), LDA is strong enough to form the enolate of acetone quantitatively. Considering its steric bulk, it removes protons selectively from the more accessible positions of the ketones which are not symmetrical like in the reaction (19). The same process can be conducted with any other sterically crowded non-nucleophilic bases.

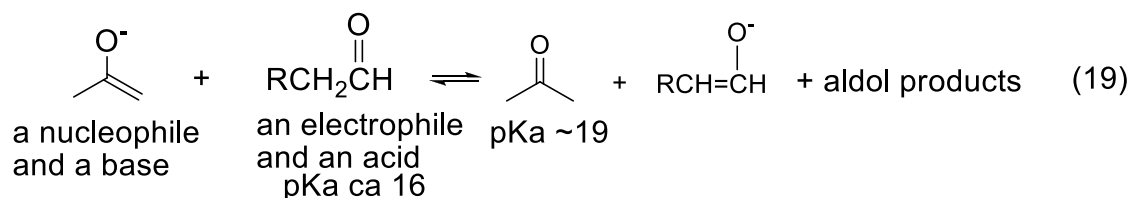


If KOH or NaOH (bases much weaker than LDA) were used for a purpose of deprotonation of acetone, the enolate would also be formed, but in equilibrium with unreacted acetone. Position of the equilibrium would be shifted towards the substrate, and the product (the enolate) would be present only in small concentration (reaction 20).

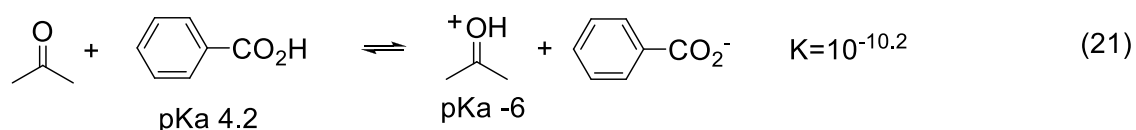
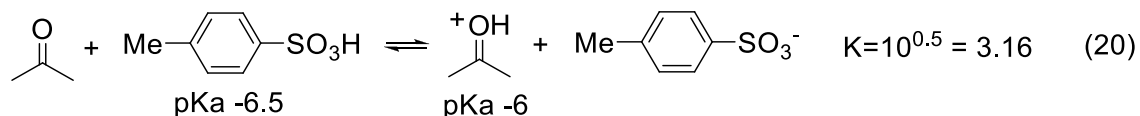


The presence of both enolate (a nucleophile) and unreacted acetone (electrophile) implies that an aldol reaction would take place. In contrast, the use of the LDA permits quantitative deprotonation, so the unreacted substrate is absent, and subsequent addition of the other carbonyl compound permits a cross-aldol reaction with full control of which component acts as a nucleophile and as an electrophile.

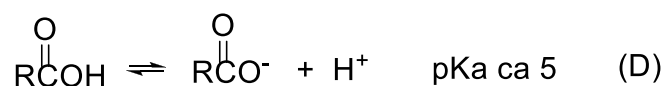
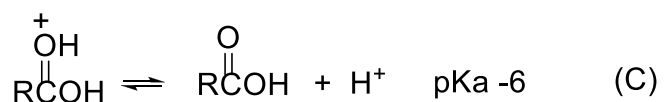
A complication arises however when the enolates derived from ketones react with enolizable aldehydes. It should be remembered that the aldehydes RCH_2CHO are stronger acids than the ketones. For example, ethanal has its pK_a of ca 16, propanal of ca 17.3, whereas acetone has pK_a of ca 19, so the ketone-derived enolate (a base) can deprotonate an aldehyde. Consequently, two enolates will be present as shown in the reaction (19), which may complicate a cross-aldol reaction. It is not our intention to discuss such specific cases.



The carbonyl groups present in carboxylic acids, aldehydes or ketones among the other compounds, are very weak bases as evidenced by their negative pK_a s of their conjugated acids as shown in the Table 1. In many reactions like esterification or formation of acetals or ketals, protonation of the carbonyl group is the first step. To achieve a reasonable concentration of the reactive species one must use very strong acids like p-toluenesulfonic acid (pK_a -6) or even stronger, like sulfuric acid or trifluoromethanesulfonic acid. Weak acids like AcOH or BzOH do not function. A comparison of protonation of acetone by strong and weak acid is shown in the reaction (20) and (21), respectively.



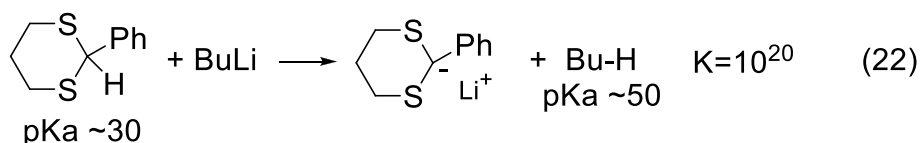
It is clearly seen that a benzoic acid (or any weak acid, like acetic acid, pK_a 4.7) is unsuitable as a catalyst for ketal/acetal formation since a concentration of the reactive protonated species is negligibly low and that the process of protonation is highly endergonic. For the same reason formation of esters from carboxylic acids and alcohols requires strong acids to initiate the process by protonation of weakly basic (pK_a -6) carbonyl group present in the $-CO_2H$ moiety. As in the case of ammonia (reactions (A) and (B)), one must not confuse the processes depicted in (C) and (D) which illustrate a capacity of a carbonyl group of a carboxylic acid to accept/lose a proton, and a capacity of a carboxyl group to lose a proton, respectively.



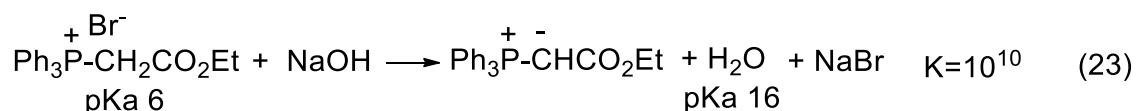
It should be stressed again, that a carbonyl group is a very weak base, whereas a carboxyl group is a reasonably strong acid.

The conversion of aldehydes into ketones can be performed via inversion of polarity at the carbonyl group also known as “umpolung”. The first stage of this procedure is deprotonation of dithioacetals.

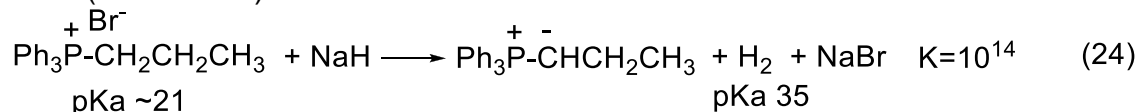
Considering weakly acidic character of dithioacetals, very strong bases must be used as shown in the reaction (22).



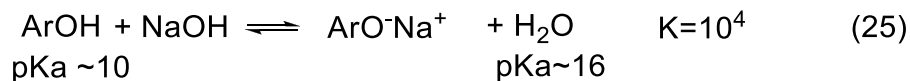
The Wittig reaction is frequently used in the organic synthesis and requires conversion of the phosphonium salts to form the ylides. Considering structures of the ylides (stabilized or non-stabilized), bases of various strength should be used to achieve deprotonation of the phosphonium salts as shown in the reaction (23) and (24) for the formation of the stabilized and non-stabilized ylides, respectively. It can be noticed that formation of the stabilized ylide from the more acidic phosphonium salt, requires less basic conditions (reaction 23). In fact, a base weaker than NaOH, like Na₂CO₃ can be used.



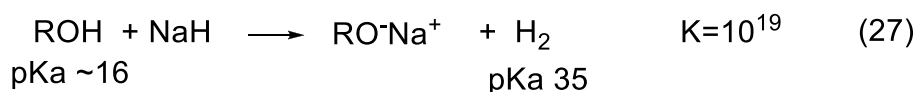
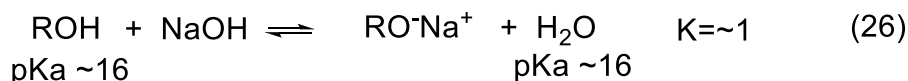
To get ylides from less acidic phosphonium salts, stronger bases like NaH or BuLi are used (reaction 24).



Deprotonation of the phenolic hydroxyl groups (pKa ~10) goes well with NaOH or KOH as shown in the reaction (25).

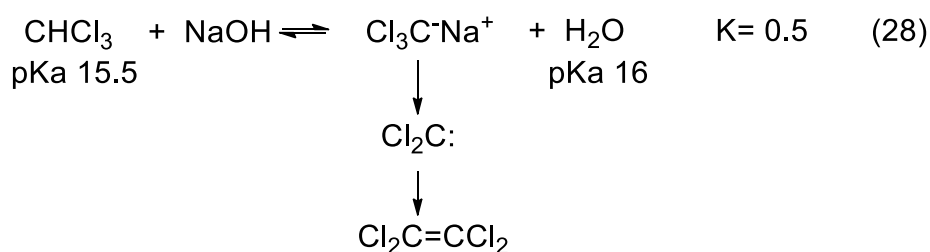


In contrast, deprotonation of hydroxyl groups present in alcohols (pKa ~16) in the same conditions furnishes mixtures of the unreacted alcohol and the alcoholate (reaction 26). Application of the stronger base like sodium hydride however, yields the alcoholate anion only as shown in the reaction (27).



Big differences of the associated Ks should be noticed in the reaction (26) and (27).

The last example is deprotonation of chloroform, a common solvent used in extractions. Neutralization of such extracts by bases is routinely performed. Some care must be exercised to use NaOH or KOH for this purpose. CHCl_3 is reasonably strong acid and can be substantially deprotonated by bases like NaOH (reaction 28).



The trichloromethyl anion formed losses the Cl^- to form dichlorocarbene, which can rapidly dimerize to form tetrachloroethylene with liberation of substantial amount of heat due to formation of the strong carbon-carbon double bond. This may result in increase of pressure in a separatory funnel and even an explosion. Thus, for safety reasons the acidic chloroform extracts must be neutralized by bases with care. Looking from a different standpoint, formation of dichlorocarbene is desirable to obtain dichlorocyclopropanes by addition to $\text{C}=\text{C}$ double bonds.

CONCLUDING REMARKS

A simple method of quantitative evaluation of the positions of the equilibria of the acid-base reactions is shown, which is based on the known pKas of the acids. To illustrate this approach a series of the acid-base processes are presented to evaluate quantitatively how strong the base should be used to achieve a reasonable concentration of the deprotonated acid. Deprotonation is frequently performed in research to get nucleophiles and yet, a quantitative treatment of the acid-base reactions is neglected in the organic chemistry textbooks just like the issue of the oxidation states of the carbon atoms, which we have addressed before.[9] Rather vague statements are used whenever preparation of the acetylide anions for example, is needed, like “strong base should be used”. It must be stated that strength of a base is a relative term. For instance, water is sufficiently strong base to deprotonate HCl ($\text{H}_2\text{O} + \text{HCl} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^-$; $K = 10^{5.3}$), whereas is a weak base to deprotonate a phenolic hydroxyl group ($\text{PhOH} + \text{H}_2\text{O} \rightarrow \text{PhO}^- + \text{H}_3\text{O}^+$; $K = 10^{-11.7}$). Conversely, there is no need to use NaH or LDA to

obtain phenolate ion since NaOH is very good for this purpose, but LDA is indispensable to obtain various types of the enolates. Thus, it seems a good idea from a didactic standpoint to present a method of evaluation of a given acid-base process quantitatively rather than to depend on words which do not transmit any quantitative meaning. We believe that the present text may be useful as a supplementary material to study the introduction to organic chemistry.

REFERENCES

1. M.B.Smith, J.March; Wiley-Interscience (2007). *March's Advanced Organic Chemistry. Reactions, Mechanisms and Structure*. 6th Ed., chapter 8 and references therein.
2. M.B.Smith; McGraw-Hill, Inc. (1994). *Organic Synthesis*. Chapter 8.5.G and references therein.
3. <https://organicchemistrydata.org/hansreich/resources/pka/>.
4. Bagno, A., Lucchini, V., Scarrano, G. *Bull.Soc.Chim Fr.* (1987), 563-572.
5. Toullec, J., *Tetrahedron Lett.* (1988), 29, 5541-5544.
6. https://organicchemistrydata.org/hansreich/resources/pka/pka_data/pka-compilation-reich-bordwell.pdf
7. Marshall, W.B., Brewbaker, J.L., Delaney, M.S. *J.Appl.Polymer Sci.* (1991), 42, 533-541.
8. Eisenhart, E.K., Bessieres, B. "Vinylolithium". *E-EROS Encyclopedia of Reagents for Organic Synthesis*. (2007), doi:[10.1002/047084289X.rv015.pub2](https://doi.org/10.1002/047084289X.rv015.pub2)
9. Silva, M.J., Lira, K.K.dM., Doboszewski, B. (2021). *African J.Chem.Educ*, 11, 82-109.

APPLICATION OF "THREE-STEP METHOD" IN CALCULATION OF CONDITIONAL POTENTIAL AND PRECIPITATION SOLUBILITY IN ANALYTICAL CHEMISTRY

Ruijia Lan¹, Li Cheng², Wenbin Su¹ and Lin Qian¹

¹Faculty of Chemistry and Material Science, Langfang Normal University, Langfang 065000,
China

²Langfang No. 1 Middle School, Langfang 065000, China

Corresponding Author Email: lanruijia@lfnu.edu.cn

ABSTRACT

According to the teaching experience, for the important and difficult knowledge "calculation of conditional potential" and "calculation of precipitation solubility" in analytical chemistry, a three-step method is summarized to solve the above problems. It aims to help students master the problem-solving method so as to solve all the similar problems and improve their scientific thinking ability. [African Journal of Chemical Education—AJCE 13(1), January 2023]

INTRODUCTION

Analytical chemistry is one of the important means to study substances and their changes. Its theories and methods are not only the basis of chemistry, but also the basis of biology, geology, environment and other disciplines. The purpose of this course in college is to enable students to establish an accurate concept of "quantity" and master the basic theories, principles and experimental techniques related to this, so as to lay a solid foundation for subsequent courses and scientific research.

In the course of many years of teaching "Analytical Chemistry" in normal university, the author has carefully analyzed the key and difficult knowledge and extracted the rules behind them, then summarized some methods that are easy for students to master. Through the transition from "teaching knowledge" to "teaching method", the students' learning abilities can be improved [1, 2], and students are able to draw inferences from one example and learn by analogy on the basis of mastering the method. For example, "three-step methods" have been summarized for calculating conditional potential and precipitation solubility.

1 "THREE-STEP METHOD" TO CALCULATE CONDITIONAL POTENTIAL

The oxidation/reduction capacity of oxidized/reduced forms of a substance can be judged by the electrode potential. The electrode potential of reversible pairs can be calculated using Nernst equation.

$$E_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{a_{\text{Ox}}}{a_{\text{Red}}} \quad (1)$$

a_{Ox} is the activity of the oxidized form, a_{Red} is the activity of the reduced form, $T=298\text{K}$, n is the number of electrons transferred in the half-reaction.

Usually, the effect of ionic strength is ignored, and the equilibrium concentrations of oxidized/reduced forms are used instead of activity, and the influence of ionic strength is not discussed in this paper.

$$E_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{[\text{Ox}]}{[\text{Red}]} \quad (2)$$

For the irreversible electric pair, the electrode potential can be estimated by the results of Nernst equation. When the Nernst equation is applied to the calculation, the changes of the oxidized and reduced forms should be considered, or the effects of side reactions should be taken into account.

$$[\text{Ox}] = c_{\text{Ox}} / \alpha_{\text{Ox}} \quad (3), \quad [\text{Red}] = c_{\text{Red}} / \alpha_{\text{Red}} \quad (4)$$

c_{Ox} , c_{Red} are the analytical concentrations of the oxidized and reduced forms, respectively. α_{Ox} , α_{Red} are the side reaction coefficients of the oxidized and reduced forms respectively.

Substitute Equation (3) and (4) into Equation (2):

$$E_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{c_{\text{Ox}} / \alpha_{\text{Ox}}}{c_{\text{Red}} / \alpha_{\text{Red}}} \quad (5)$$

When $c_{\text{Ox}} = c_{\text{Red}} = 1 \text{ mol} \cdot \text{L}^{-1}$,

$$E_{\text{Ox/Red}}^{\theta'} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{\alpha_{\text{Red}}}{\alpha_{\text{Ox}}} \quad (6)$$

$E^{\theta}_{\text{Ox/Red}}$ is called the conditional potential [3]. Then the Nernst equation becomes the following form:

$$E_{\text{Ox/Red}} = E^{\theta}_{\text{Ox/Red}} + \frac{0.059}{n} \lg \frac{c_{\text{Ox}}}{c_{\text{Red}}} \quad (7)$$

The value of the conditional potential is not only related to the standard electrode potential E^{θ} , but also to the side reaction coefficient. Therefore, the conditional potential is not only affected by the temperature, but also by the acidity of the solution, the concentration of complexing agent and other factors. It is constant only when the conditions are certain, and the conditional potential is also named. The calculation of conditional potential can help students to understand the meaning of conditioned potential and the factors that affect conditioned potential. Based on years of analytical chemistry teaching experience, the author found that the calculation of conditional potential is a difficult point for students to learn for many reasons. For example, some students have a poor grasp of the Nernst equation itself, while others confuse conditional potential with standard electrode potential and some other concepts learned in inorganic chemistry. In order to help students master this difficult content, the "three-step method" for calculating conditional potentials has been summarized. Students can solve all kinds of problems in calculating conditional potentials as long as they follow these three steps. The specific application examples of the three-step method are shown in Table 1.

Table 1 Three-step method to calculate conditional potential

| | Effect of precipitation formation on conditional potential | Effect of complex formation on conditional potential | Effect of acidity on conditional potential |
|--|--|--|---|
| | Example: Calculate the conditional potential of the $\text{Cu}^{2+}/\text{Cu}^+$ couple in the presence of I^- | Example: Calculate the conditional potential of the $\text{Fe}^{3+}/\text{Fe}^{2+}$ couple in the presence of F^- | Example: Investigating the effect of acidity on the $\text{H}_3\text{AsO}_4/\text{HAsO}_2$ redox couple |
| Step 1 Write the Nernst equation in terms of the half-reaction | half-reaction: $\text{Cu}^{2+} + \text{e}^- \rightleftharpoons \text{Cu}^+$ Nernst equation: $E = E_{\text{Cu}^{2+}/\text{Cu}^+}^0 + 0.059 \lg \frac{[\text{Cu}^{2+}]}{[\text{Cu}^+]}$ | half-reaction: $\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$ Nernst equation: $E = E_{\text{Fe}^{3+}/\text{Fe}^{2+}}^0 + 0.059 \lg \frac{[\text{Fe}^{3+}]}{[\text{Fe}^{2+}]}$ | half-reaction: $\text{H}_3\text{AsO}_4 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{HAsO}_2 + 2\text{H}_2\text{O}$ Nernst equation: $E_{\text{H}_3\text{AsO}_4/\text{HAsO}_2} = E_{\text{H}_3\text{AsO}_4/\text{HAsO}_2}^0 + \frac{0.059}{2} \lg \frac{[\text{H}_3\text{AsO}_4][\text{H}^+]^2}{[\text{HAsO}_2]}$ |
| Step 2 Replace the equilibrium concentrations of oxidized/reduced forms in the Nernst equation with the analytical concentrations | Cu^{2+} has no side reactions, so $[\text{Cu}^{2+}] = c_{\text{Cu}^{2+}}$ Cu^+ has a side reaction: $\text{Cu}^+ + \text{I}^- = \text{CuI} \downarrow$, $[\text{Cu}^+][\text{I}^-] = K_{\text{sp}} \text{CuI}$ so $[\text{Cu}^+] = K_{\text{sp}}/[\text{I}^-]$ (2) Substitute equations (1) and (2) into Nernst equation, and get: $E = E_{\text{Cu}^{2+}/\text{Cu}^+}^0 + 0.059 \lg \frac{c_{\text{Cu}^{2+}}}{K_{\text{sp}}/[\text{I}^-]}$ | Fe^{2+} has no side reactions, so $[\text{Fe}^{2+}] = c_{\text{Fe}^{2+}}$ Fe^{3+} undergoes the following side reaction: $\text{Fe}^{3+} + \text{F}^- = \text{FeF}^{2+}$, $\text{FeF}^{2+} + \text{F}^- = \text{FeF}_2^+$, $\text{FeF}_2^+ + \text{F}^- = \text{FeF}_3$ According to the definition of the side reaction coefficient, $\alpha_{\text{Fe}^{3+}(\text{F})} = \frac{[\text{Fe}^{3+}] + [\text{FeF}^{2+}] + [\text{FeF}_2^+] + [\text{FeF}_3]}{[\text{Fe}^{3+}]} = \frac{c_{\text{Fe}^{3+}}}{[\text{Fe}^{3+}]}$ therefore $[\text{Fe}^{3+}] = \frac{c_{\text{Fe}^{3+}}}{\alpha_{\text{Fe}^{3+}(\text{F})}}$ Substitute equations (1) and (2) into Nernst equation, and get: $E = E_{\text{Fe}^{3+}/\text{Fe}^{2+}}^0 + 0.059 \lg \frac{c_{\text{Fe}^{3+}}/\alpha_{\text{Fe}^{3+}(\text{F})}}{c_{\text{Fe}^{2+}}}$ | Because H_3AsO_4 is triprotic acid, the distribution fraction of H_3AsO_4 is $\delta_{\text{H}_3\text{AsO}_4} = \frac{[\text{H}_3\text{AsO}_4]}{[\text{H}_3\text{AsO}_4] + [\text{H}_2\text{AsO}_4^-] + [\text{HAsO}_4^{2-}] + [\text{AsO}_4^{3-}]}$ $= \frac{[\text{H}_3\text{AsO}_4]}{c_{\text{H}_3\text{AsO}_4}}$ hence $[\text{H}_3\text{AsO}_4] = c_{\text{H}_3\text{AsO}_4} \delta_{\text{H}_3\text{AsO}_4}$ similarly $[\text{HAsO}_2] = c_{\text{HAsO}_2} \delta_{\text{HAsO}_2}$ Substitute equations (1) and (2) into Nernst equation, and get: $E = E_{\text{H}_3\text{AsO}_4/\text{HAsO}_2}^0 + \frac{0.059}{2} \lg \frac{c_{\text{H}_3\text{AsO}_4} \delta_{\text{H}_3\text{AsO}_4} [\text{H}^+]^2}{c_{\text{HAsO}_2} \delta_{\text{HAsO}_2}}$ |
| Step 3 According to the algorithm of | According to the rules of the logarithmic algorithm, the following formula is obtained | According to the rules of the logarithmic algorithm, the following formula is obtained | According to the rules of the logarithmic algorithm, the following formula is obtained |

| | | | |
|--|---|--|---|
| <p>logarithm, the term containing analytical concentrations is separated out alone and the sum of the other two terms is the conditional potential</p> | $E = E_{\text{Cu}^{2+}/\text{Cu}^+}^{\theta} + 0.059 \lg([\text{I}^-]/K_{\text{sp}}) + 0.059 \lg c_{\text{Cu}^{2+}}$ <p>Add the first two items on the right of the equal sign to get the conditional potential</p> $E^{\theta'} = E_{\text{Cu}^{2+}/\text{Cu}^+}^{\theta} + 0.059 \lg([\text{I}^-]/K_{\text{sp}})$ | $E = E_{\text{Fe}^{3+}/\text{Fe}^{2+}}^{\theta} + 0.059 \lg \frac{1}{\alpha_{\text{Fe}^{3+}(\text{F}^-)}} + 0.059 \lg \frac{c_{\text{Fe}^{3+}}}{c_{\text{Fe}^{2+}}}$ <p>Add the first two items on the right of the equal sign to get the conditional potential</p> $E^{\theta'} = E_{\text{Fe}^{3+}/\text{Fe}^{2+}}^{\theta} + 0.059 \lg \frac{1}{\alpha_{\text{Fe}^{3+}(\text{F}^-)}}$ | $E = E_{\text{H}_3\text{AsO}_4/\text{HAsO}_2}^{\theta} + \frac{0.059}{2} \lg \frac{[\text{H}^+]^2 \delta_{\text{H}_3\text{AsO}_4}}{\delta_{\text{HAsO}_2}} + \frac{0.059}{2} \lg \frac{C_{\text{H}_3\text{AsO}_4}}{C_{\text{HAsO}_2}}$ <p>Add the first two items on the right of the equal sign to get the conditional potential</p> $E^{\theta'} = E_{\text{H}_3\text{AsO}_4/\text{HAsO}_2}^{\theta} + \frac{0.059}{2} \lg \frac{[\text{H}^+]^2 \delta_{\text{H}_3\text{AsO}_4}}{\delta_{\text{HAsO}_2}}$ |
|--|---|--|---|

It can be seen from the above table that when calculating the conditional potential in the three-step method, the first step must be to write the Nernst equation correctly, which is the basis of the three-step method. Write the equilibrium concentration of the oxidized form on the numerator of the logarithmic term and write the equilibrium concentration of the reduced form on the denominator, that is $E_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{[\text{Ox}]}{[\text{Red}]}$. If there are H^+ and OH^- in the half-reaction, then $[\text{H}^+]$ and $[\text{OH}^-]$ also appear in the Nernst equation. The second step is the "key step", in which the transition from the equilibrium concentration to the analytical concentration should be completed. First, write down the side reactions of oxidized and reduced forms: the formation of precipitation, the occurrence of complexation reactions, the occurrence of acid dissociation or basic dissociation, and so on.

Then according to the definition formula of solubility product constant K_{sp} , the definition formula of the side reaction coefficient and distribution fraction, the mathematical relationships between the equilibrium concentrations of the oxidized and reduced forms and their analytical concentrations are deduced. The equilibrium concentrations are expressed by the expressions containing the analytical concentrations, and then they are substituted into the Nernst equation to obtain the following formula $E_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{c_{\text{Ox}}/\alpha_{\text{Ox}}}{c_{\text{Red}}/\alpha_{\text{Red}}}$ or $E_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{c_{\text{Ox}} \cdot \delta_{\text{Ox}}}{c_{\text{Red}} \cdot \delta_{\text{Red}}}$ (Here, take those containing side reaction coefficients and distribution fraction s as examples, and other examples containing K_{sp} are shown in Table 1). The difficulty of this step mainly involves the side

reaction coefficient mentioned in the chapter of complexometric titration and the distribution fraction mentioned in the chapter of acid-base titration. If these two important concepts are not mastered well, the conditional potential cannot be calculated correctly. In other words, the calculation of conditional potential is actually a comprehensive application of the knowledge learned from acid-base equilibrium, complexation equilibrium, precipitation dissolution equilibrium and oxidation-reduction equilibrium. In the third step, according to the algorithm of logarithm, separate out the term containing analytical concentrations alone (that is

$$E_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{\alpha_{\text{Red}}}{\alpha_{\text{Ox}}} + \frac{0.059}{n} \lg \frac{c_{\text{Ox}}}{c_{\text{Red}}}$$

or $E_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{\delta_{\text{Ox}}}{\delta_{\text{Red}}} + \frac{0.059}{n} \lg \frac{c_{\text{Ox}}}{c_{\text{Red}}}$) and the sum of the other two terms on the right of the equal

sign is the conditional potential $E'_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{\alpha_{\text{Red}}}{\alpha_{\text{Ox}}}$ or $E'_{\text{Ox/Red}} = E_{\text{Ox/Red}}^{\theta} + \frac{0.059}{n} \lg \frac{\delta_{\text{Ox}}}{\delta_{\text{Red}}}$. The

second term on the right of the equal sign includes the effects of various external conditions on the potential, so the sum of the two terms is called the conditional potential.

2 "THREE-STEP METHOD" TO CALCULATE THE SOLUBILITY OF PRECIPITATES

The second typical case is for another important point of knowledge "solubility calculation", the "three-step method" was also summarized to calculate the solubility of the precipitation under various conditions. Table 2 demonstrates how to apply the three-step method to calculate the effects of common ion effect, acid effect and complex effect on solubility.

Table 2 Three-step method to calculate solubility

| | Common Ion Effect e.g. Add excess SO_4^{2-} to the Ba^{2+} solution until $[\text{SO}_4^{2-}] = 0.01 \text{ mol} \cdot \text{L}^{-1}$, calculate the solubility of BaSO_4 in this case. | Acid Effect e.g. Calculate the solubility of CaC_2O_4 at $\text{pH}=2$ | Complex Effect e.g. Calculate the solubility of AgCl in $0.10 \text{ mol} \cdot \text{L}^{-1} \text{Cl}^-$. |
|--|---|--|---|
| Step 1 Write down the precipitation-dissolution equilibrium (main reaction), side reactions, and the relationship between the equilibrium concentration of configurational ions and the solubility S | $\text{BaSO}_4(\text{s}) \rightleftharpoons \text{Ba}^{2+} + \text{SO}_4^{2-}$ $\text{S} \qquad 0.01 + \text{S}$ <p>$[\text{Ba}^{2+}]$ is equal to solubility S, and $[\text{SO}_4^{2-}]$ is equal to $0.01 + \text{S}$.</p> | $\text{CaC}_2\text{O}_4(\text{s}) \rightleftharpoons \text{Ca}^{2+} + \text{C}_2\text{O}_4^{2-}$ $\text{S} \qquad \updownarrow \text{H}^+$ HC_2O_4^- $\text{H}_2\text{C}_2\text{O}_4$ $[\text{C}_2\text{O}_4^{2-}] + [\text{HC}_2\text{O}_4^-] + [\text{H}_2\text{C}_2\text{O}_4]$ $= [(\text{C}_2\text{O}_4^{2-})'] = \text{S}$ <p>The main reaction is the dissolution of CaC_2O_4 to produce Ca^{2+} and $\text{C}_2\text{O}_4^{2-}$, and the side reaction is the combination reaction of $\text{C}_2\text{O}_4^{2-}$ and H^+ (acid effect). $[\text{Ca}^{2+}]$ is equal to the solubility S. Due to the occurrence of side reactions, $[(\text{C}_2\text{O}_4^{2-})']$ is equal to S, but $[\text{C}_2\text{O}_4^{2-}]$ isn't equal to S.</p> | $\text{AgCl}(\text{s}) \rightleftharpoons \text{Cl}^- + \text{Ag}^+$ $0.1 + \text{S} \qquad \updownarrow \text{Cl}^-$ $\text{AgCl}, \text{AgCl}_2^-, \dots$ $[\text{Ag}^+] + [\text{AgCl}] + [\text{AgCl}_2^-] + [\text{AgCl}_3^{2-}] + [\text{AgCl}_4^{3-}]$ $= [(\text{Ag}^+)] = \text{S}$ <p>The main reaction is the dissolution of AgCl to produce Ag^+ and Cl^-, and the side reaction is the complexation effect occurring between Ag^+ and Cl^-. The $[\text{Cl}^-]$ is equal to $0.1 + \text{S}$ (common ion effect) and because of the side reaction, $[(\text{Ag}^+)]$ is equal to the solubility S but $[\text{Ag}^+]$ is not equal to S.</p> |

| | | | |
|--|---|---|---|
| <p>Step 2 According to the definition of the solubility product constant K_{sp} and the relationship between the equilibrium concentration of configurational ions and the solubility S, a set of equations is created</p> | $\begin{cases} [\text{Ba}^{2+}] = S & (1) \\ [\text{SO}_4^{2-}] = 0.01 + S \approx 0.01 & (2) \\ K_{sp} = [\text{Ba}^{2+}][\text{SO}_4^{2-}] & (3) \end{cases}$ | $\begin{cases} [\text{Ca}^{2+}] = S & (1) \\ [(\text{C}_2\text{O}_4^{2-})'] = S & (2) \\ K_{sp} = [\text{Ca}^{2+}][\text{C}_2\text{O}_4^{2-}] = [\text{Ca}^{2+}] \frac{[(\text{C}_2\text{O}_4^{2-})']}{\alpha_{\text{C}_2\text{O}_4^{2-}(\text{H}^+)}} & (3) \end{cases}$ | $\begin{cases} [\text{Cl}^-] = 0.1 + S \approx 0.1 & (1) \\ [(\text{Ag}^+)'] = S & (2) \\ K_{sp} = [\text{Cl}^-][\text{Ag}^+] = [\text{Cl}^-] \frac{[(\text{Ag}^+)']}{\alpha_{\text{Ag}^+(\text{Cl}^-)}} & (3) \end{cases}$ |
| <p>Step 3 The solubility S is calculated by solving the system of equations</p> | <p>Substitute equations (1) and (2) into equation (3) to obtain the formula for S:</p> $S = \frac{K_{sp}}{0.01}$ | <p>Substitute equations (1) and (2) into equation (3) to obtain the formula for S</p> $S = \sqrt{K_{sp} \alpha_{\text{C}_2\text{O}_4^{2-}(\text{H}^+)}}$ | <p>Substitute equations (1) and (2) into equation (3) to obtain the formula for S</p> $S = \frac{K_{sp} \cdot \alpha_{\text{Ag}^+(\text{Cl}^-)}}{0.10}$ |

It can be seen from Table 2 that the solubility is calculated according to the "three-step method": the first step is to write the main reaction and side reactions, which is the basis of the three-step method. To calculate the solubility correctly, it is necessary to know all the reactions that occur in the system. It is important to note that when a side reaction occurs, such as an acid effect, $[\text{C}_2\text{O}_4^{2-}]$ is no longer equal to solubility S , but $[(\text{C}_2\text{O}_4^{2-})'] (= [\text{C}_2\text{O}_4^{2-}] + [\text{HC}_2\text{O}_4^-] + [\text{H}_2\text{C}_2\text{O}_4])$, the total concentration of all the oxalate species in equilibrium, i.e. analysis concentration of all the oxalate species) is equal to solubility S . The same is true when a complexation effect occurs, where $[\text{Ag}^+]$ is not equal to S , but $[(\text{Ag}^+)] (= [\text{Ag}^+] + [\text{AgCl}] + [\text{AgCl}_2^+] + [\text{AgCl}_3^{2+}] + [\text{AgCl}_4^{3+}])$, the total concentration of all the Ag^+ species in equilibrium) is equal to the solubility S . In the second step, a system of equations is established based on the definition of solubility product and the relationship between the equilibrium concentration of constitutive ions and solubility S . This step is the core of the three-step method and the step where the difficulties are concentrated.

The thing to note in this step is that the third equation for K_{sp} should not be written as an equation for the conditional solubility product constant K'_{sp} [3]. K_{sp} is constantly equal to the equilibrium concentration of the configurational cation multiplied by the equilibrium concentration of the configurational anion. In contrast, K'_{sp} is equal to product of the analysis concentration of the configurational cation and anion and it varies with the composition of the solution. Therefore, when calculating solubility, it is recommended to use K_{sp} instead of K'_{sp} . Since the relationship between the equilibrium concentration of the configurational ion and the analytical concentration is involved

in this step, the concept of the side reaction coefficient is used again. In the third step, the formula for solubility is obtained by substituting the first and second equations into the third equation. In this step, the coefficients of the side reactions involved need to be calculated correctly. Regarding the formula of S, it can be briefly summarized that when there is a common ion effect, the formula of S is in the form of fraction; when there is no common ion effect, only acid or complex effect, the formula of S exists in the form of a square root $\sqrt{K_{sp} \cdot \alpha}$, where α represents coefficient of the side reaction.

For the above two important points of knowledge, we have summarized and taught students the three-step method, so that they can solve the same type of problem on the basis of mastering the method. By learning these methods, students are actually taught to see the essence through the phenomena and find the regularity behind the complicated apparent phenomena. This is beneficial to the development of chemistry students' ability to think logically and summarize inductively [4,5].

ACKNOWLEDGEMENTS

This research has been supported by “The key reform project of education and teaching of Langfang Normal University: Based on a blended teaching model, creating a gold course in analytical chemistry, project number: K2019-7”

REFERENCES

1. Tenaw, Y. (2013). Relationship between self-efficacy, academic achievement and gender in analytical chemistry at debre markos college of teacher education. *African Journal of Chemical Education*, 3(1).
2. Zhang, P. P., Gan, L., Tian, L. Ding, Z. Q., and Tang C. Q. (2022). Preliminary Study on the Teaching Reform of Analytical Chemistry Course Guided by the Cultivation of Innovation

- Ability Taking Applied Chemistry as Example [J]. *Chinese Journal of Chemical Education*, 43(6):9-13.
3. Analytical Chemistry. 4th Edition. Central China Normal University, etc. Higher Education Press, 2011.
 4. Ford, R., George, A., Molina, C., and Mason, D. (2014). Measuring the effects of class scheduling on student success in secondary school chemistry using content-based versus logical thinking-based online commercial programs. *African Journal of Chemical Education*, 4(3), 133-149.
 5. Chen, H. X., Ge, Y. L., Wang, S. F., Zhang X. H., and Huang J. L. (2022). Study on the Reform of Analytical Chemistry Blended Teaching Oriented to Ability Training. *Chinese Journal of Chemical Education*, 43(8):61-65.

CHEMICAL COMPOSITION ANALYSIS OF PALM OILS IN IJEBU-ODE, OGUN STATE

Samson Oluwasegun Aruna

Department of Chemical Science, College of Science, Tai Solarin University of Education, Nigeria

Email: aruna.samsonsegun@gmail.com

ABSTRACT

Palm oil is one of the major fats and oils produced in Nigeria. It forms an important ingredient in the diet of many people in Ijebu-ode Ogun State, Nigeria. The quality of palm oil is mostly determined by the following parameters: Free Fatty Acid (FFA) content, Iodine Value (IV), Peroxide Value (PV), Moisture Content, Saponification Value (SV) and Impurity Content. This study attempts to investigate the chemical composition analysis of palm oil. sold in major markets in Ijebu-Ode, Ogun State, Nigeria. Twenty branded and unbranded palm oil samples were collected from three markets in Ijebu-Ode. They were analyzed for saponification value. Acid value and peroxide value using [1][2]. The results obtained showed that the Saponification value (SV) ranges from 183.03 ± 0.15 - 220.89 ± 0.05 mgKOH/g. Acid value (AV) from 8.64 ± 0.10 - 12.96 ± 0.05 mgKOH/g and Peroxide value (PV) from 7.50 ± 0.10 - 15.00 ± 0.15 meq/kg. All the parameters investigated had values within the [3]/[4] standards. It can thus be concluded that palm oil from Ijebu-ode has a good shelf-life, is suitable for both domestic and industrial applications and there is no evidence of adulteration notable from their chemical compositional analysis. [*African Journal of Chemical Education—AJCE 13(1), January 2023*]

INTRODUCTION

Foods are any substances that provide nutritional support that the body needs. It is mostly gotten from plants or animals and houses essential nutrients like carbohydrates, fats, proteins, vitamins or minerals. Foods are categorized into several classes based on the type of nutrient they contain and the functions they perform in the body. These classes are carbohydrates, protein, vitamins, fat, minerals, and water.

Fat is a macronutrient. It is needed by the body for energy, cell structure and functioning. Based on physical characteristics, fats are categorized as saturated and unsaturated. Saturated fats are solid at room temperature. Foods such as butter, cheese and the white marbling in steak are good examples of saturated fat. Unsaturated fats on the other hand are liquid at room temperature and they include food such as Olive, cottonseed, soya and palm oils. An oil is any neutral, nonpolar chemical substance that is a viscous liquid at ambient temperatures and is both hydrophobic/water fearing and lipophilic/fat Loving. Oils may have their origin from animals, vegetables, or petrochemicals. Oils are used for food, fuel, lubrication, and the manufacture of products like paints, plastics, and other minerals.

Vegetable oil can be gotten from tree crops, animal crops and as byproducts. Most vegetables are obtained from beans (soyabeans) or seeds (cottonseed), which generally furnish two valuable commodities- oil and a protein-rich meal. Seeds are extracted by pressing or by solvent extraction or a combination of both. Oils such as palm oil and Olive, on the other hand, are pressed out of the

soft fruits (endosperm). Seeds give oils in different proportions. In 2000, world average oil yields were Soyabean (18.3%) rapeseed (38.6%), sunflower (40.9%) groundnut (40.73%), cottonseed (15.1%), coconut (62.4%), palm kernel (44.6%), sesame (42.4%), and linseed (33.5%), average for all oilseeds (25.8%) [5]. In addition, yields from palm fruit (40-50%), Olive (25-30%), and corn (about 5%) are as indicated [5]. Some oils, such as virgin olive oil do not require further treatment, but most are refined to an extent before use. Vegetable oil is an important material for mankind's survival. Therefore, the edible vegetable oil quality and supervision become big problems for the national economy and people's health. However, to reap huge gains and meet up with the high rate of demand, manufacturers add shoddy animal oils to vegetable oil, for instance, oils extracted from chicken, duck and even the body of dead animals [6].

The oil palm (West Africa's most important oil-producing plant) fruit produces two distinct types of oils: crude palm oil which has an orange red color, extracted from the fruit's mesocarp and crude palm kernel oil which has a brownish-yellow color, extracted from the seeds (that is, kernel). Palm oils consist of mainly palmitic and oleic acids and palm kernel oil contains mainly Lauric acid. Red palm oil (RPO), besides providing calorie density to the diet, is also the richest natural source of β -carotene, a precursor of vitamin A and an antioxidant that destroys singlet oxygen and free radicals [7]. Palm oil is the richest natural source of carotenoids in terms of retinol (provitamin A) equivalent [8]. According to [9], palm oil serves as an antioxidant because it contains vitamin E, and also contains about 45% tocophenols and 55% tocotrienols. The carotenoids (500-700ppm) are

responsible for the characteristic deep orange-red color [5]; while its semi-solid consistency at tropical room temperature is mainly due to the presence of triacylglycerols of palmitic and oleic acids [10]. Palm oil is unique among vegetable oils in having a significant amount of saturated acids (10-15%) at the 2-position of its triacylglycerols (TAGS) [5]. The quality of palm oil is mostly determined by the following parameters: free fatty acid (FFA) content, Iodine value (IV), Peroxide value (PV), moisture content, saponification value (SV) and impurity content. The chemical composition analysis is the determination of these parameters which are relatively used as an index of adulteration or deterioration of the oil.

In Nigeria, the high demand (consumption) for palm oil which is growing faster than supply (production) has created a wide gap. This widening gap between demand and production has resulted in increasing reports of adulteration [12]. Adulteration of fats and oils has been the subject of many studies since it is an old problem. The practice has been to sell cheaper oils in place of or mixed with more expensive oils. Adulteration of palm oil has gained widespread speculation in Nigeria. Palm oil producers in order to increase the quantity produced and maximize profit have reportedly adulterated palm oil, failing to consider the effects this adulteration might have on the quality of the palm oil and the consumers. The adulterants reportedly used include carrot, papaya, natural potash and red dye; with potash and red dye being the preferred and most widely used adulterants due to their abundance and low cost.

The problem under consideration in this study is to determine the chemical compositional analysis of palm oils in Ijebu-Ode local government of Ogun states. Thus, the study is meant to analyze the oil samples for their saponification value, fatty acid value, and peroxide value. Different researchers have also worked on the analysis of palm oils and their adulteration in various parts of the world, like Malaysia, India and the Western parts of Nigeria. But this study focuses on Ijebu-Ode area. Past research such as those reported by [12][13], to mention a few, had focused on the analysis and characteristics of these adulterants using complex analytical tools such as gas chromatography, High-Pressure Liquid Chromatography, FTIR e.t.c. So far, there are very few studies and research on the analysis of palm oil samples using titrimetric methods. Also, there is little data on chemical compositional analysis in the region. The present study attempts to minimize the cost, stress and availability of the procedure by carrying out the determination using the titrimetric method of analysis. This study is confined to chemical compositional analysis and determination of adulterants in palm oils in Ijebu-Ode local government area, Ogun State, Nigeria. The study is centred on palm oils from Ijebu-Ode markets only, it does not include other parts of the country.

CHEMICAL COMPOSITION OF PALM OIL

Free Fatty Acid (FFA)

Free fatty acid reflects the amount of fatty acid hydrolyzed from triacylglycerols. According to SON, the standard level of FFA for palm oil is between 3.5 and 5%. The FFA value can be affected by the duration of storage of the fruit used to possess the Palm oil and the length of storage of palm oil after processing [14]. Long storage of the palm fruit results in over-ripe thereby leading to a high level of FFA [15]. In the study [16] it was reported that adulteration is another factor that also affects the FFA value of palm oil. [17] reported that a high FFA value has a high tendency of decreasing the ability of the liver to store sugar.

Saponification Value (SV)

Saponification value is a measure of the average weight of all the fatty acids present. It can also be said to mean the chain length of the FFA. As the saponification value of the palm oil increases, the molecular weight of the oil decreases vis-versa. According to the standard organization of Nigeria, saponification value for palm oil ranges between 190 and 209 mgKOH/g. A significantly high proportion of saponification value of palm oil (260.22 ± 1.38 mgKOH/g) suggests that the oil can be used for soap production [18] but is not unsuitable for human nutrition (consumption) [19]. Adulteration increases the saponification value of palm oil making palm oil a good raw material for soap making [18]. [20] reported that palm oils with saponification value within the range of 195.76 - 198.75 mgKOH/g show no evidence of adulteration and are suitable for both domestic and

industrial uses. This is in accordance with [21] findings that palm oils with saponification values from 129.04 – 198.03 mgKOH/g are not adulterated and are suitable for domestic and industrial applications as well as export trade.

Acid value (AV)

Acid value is a relative measure of rancidity as free fatty acids are normally formed during the decomposition of oil glycerides. The accepted acid value for palm oil as recommended by [3] and [22] is from 10 - 15%. Like other parameters, Adulteration also has the potential of increasing the acid value of Palm oil thereby making the oil less quality [16]. A high acid value is unset of rancidity. Oils that taste or smell unpleasant will consequently have high acid value. Increased acid value is probably caused by a variety of agents: Presents of moisture in the oil, elevated temperature and so on [6]. According to [23] acid value of 12.06 + 0.4 0mgKOH/g or above indicates high FFA and leads to the tendency to become rancid.

Peroxide Value (PV)

Peroxide Value which determines the shelf life of the oil is a measure of oxidation of the palm oil. High peroxide value shows that the oil has been oxidized while low peroxide value means that the oil can stay longer without being oxidized. Like acid value, Peroxide value is another useful indicator of rancidity. It indicates an early stage of rancidity occurring under mild conditions. Standard peroxide value as recommended by [3] and [22] is 10meq/Kg. [20] stated that peroxide value from 7.80 to 8.40meq/Kg shows no evidence of adulteration and are good for domestic and

industrial application. This is in accordance with the report of [21] that palm oils with peroxide values within the range of 7.90 to 8.80meq/Kg are of good quality. Adulteration of palm oil with adulterants such as red dye reduces the peroxide value of the oil. Consequently, formation of peroxides in unadulterated palm oil occurs at a faster rate compared to adulterated palm oil and may be attributed to the presence of naturally occurring antioxidants in the red dye [12]. [16] also reported that adulteration of palm oil with red dye reduces the peroxide value of the palm oil to 12.00meq/Kg significantly lower than the SON/NIS standard. The oxidation stability of palm oil is a major advantage of the oil. Greater peroxide value is an indication of high oxidation of the oil. Peroxide values between 20 to 40meq/Kg mostly have a rancid taste [11].

METHODOLOGY

Sample and Sampling Techniques

Twenty samples of palm oils were collected for this study. Two different brands of palm oil (namely Kings and Marmador palms oil and eighteen (18) locally processed palm oils were collected from three markets in Ijebu-Ode, Ogun State. Among the various markets in Ijebu-Ode; New-market, Itale and Oke-aje markets were purposely selected for sampling. The rationale for the selection of these markets is to enable the researcher to have a narrowed-down population from which the sample can be drawn. The oils were randomly purchased from each market. These markets were selected because they are the most patronized markets in Ijebu-Ode. Samples were collected

and tightly packed in a container to prevent further oxidation or contamination and kept in the laboratory away from sunlight.

Sample Coding

Tablet 1: Sample codes and their location or brand

| S/N | Sample Code | Brand/Location |
|-----|-------------|-------------------------------------|
| 1 | A | Kings Palm Oil |
| 2 | B | Marmador Palm Oil |
| 3 | C1 – C6 | Local Palm oils from New Market |
| 4 | D1 – D6 | Local Palm oils from Oke-Aje Market |
| 5 | E1 – E6 | Local Palm oils from Itale Market |

Methods for the Determination of Chemical Composition of Palm Oil

1. Determination of Saponification Value

Approximately 2g of each of the oil samples were respectively weighed into different conical flasks and 25ml of ethanolic potash was added. To another flask was added the same quality and quantity of the ethanolic potash but omitting the oil sample, this was used as blank. All the flasks were boiled in a water bath for 30 minutes with frequent shaking. Two drops of phenolphthalein indicator were added to each flask and titrated with 0.5M HCL with vigorous shaking without delay until the pink color just disappeared and the volume of titrant used was recorded. The titration was

repeated twice for each sample. The Saponification number (or value) of each sample was calculated as follows:

$$\text{Saponification Value} = \frac{(B - S) \times M \times 56.1}{W}$$

Where: Saponification value is measured in mgKOH/g of sample

B = Volume of titrant (ml) for blank

S = Volume of titrant (ml) for Sample

M = Molarity of HCL (mmol/ml)

56.1 = Molecular weight (MW) of KOH (mg/mmol)

W = Sample mass (g)

2. Determination of Acid Value

Twenty-five (25mL) of ethanol was added to 1.5g of each oil sample contained in different conical flasks. The mixture was boiled in a water bath and left to cool followed by the addition of two drops of phenolphthalein indicator. The mixture was titrated with 0.1M NaOH with constant shaking for proper mixing until the endpoint was reached. This is indicated by a slight pink colour that persists for 30s. The volume of titrant used was recorded. The titration was repeated twice for each sample. The acid value of each sample was calculated using the formula below:

$$\text{Acid Value} = \frac{V \times M \times 56.1}{W}$$

Where:

V = Volume of NaOH titrant (ml)

M = Molarity of NaOH titrant (mol/1000mL)

W = Sample mass (g)

3. Determination of Peroxide Value

The method reported by [1] was used. 2g each of the oil samples were respectively weighed into different flasks and 15ml of the mixture of acetic acid (CH_3COOH) -chloroform (CHCl_3) in the ratio of 3:2 respectively was added to the oil sample. 0.5mL saturated potassium iodide was added to each conical flask and allowed to stand for five (5) minutes, thereafter, 15mL of distilled water was added and titrated with 0.1M $\text{Na}_2\text{S}_2\text{O}_3$ until a yellowish colour disappeared, then 0.5ml of starch was added and Titration continued to a colourless endpoint. The volume of titrant used was recorded. The titration was repeated twice for each sample. The peroxide value for each sample was calculated from the equation as follows:

$$\text{Peroxide Value} = \frac{(S - B) \times M \times 1000}{W}$$

Where: Saponification value is measured in meq/Kg of sample

B = Volume of titrant (mL) for blank

S = Volume of titrant (mL) for Sample

M = Molarity of $\text{Na}_2\text{S}_2\text{O}_3$ solution (meq/mL)

1000 = Conversion of Units (g/Kg)

W = Sample mass (g)

RESULTS AND DISCUSSION

Table 2: Chemical composition of palm oils in Ijebu-Ode

| S/N | Samples | Saponification Value (mgKOH/g) | Acid Value (mgKOH/g) | Peroxide Value (meq/Kg) |
|------------|---------|-----------------------------------|-------------------------|----------------------------|
| 1 | A | 215.28 ± 0.15 | 8.81 ± 0.15 | 7.50 ± 0.10 |
| 2 | B | 210.38 ± 0.10 | 9.09 ± 0.10 | 10.00 ± 0.05 |
| 3 | C1 | 206.87 ± 0.15 | 10.04 ± 0.15 | 10.00 ± 0.05 |
| 4 | C2 | 211.08 ± 0.15 | 11.05 ± 0.05 | 7.50 ± 0.10 |
| 5 | C3 | 193.55 ± 0.10 | 9.26 ± 0.15 | 12.50 ± 0.10 |
| 6 | C4 | 220.89 ± 0.05 | 9.37 ± 0.05 | 10.00 ± 0.15 |
| 7 | C5 | 199.86 ± 0.15 | 9.59 ± 0.05 | 15.00 ± 0.05 |
| 8 | C6 | 201.26 ± 0.15 | 12.01 ± 0.10 | 15.00 ± 0.15 |
| 9 | D1 | 194.95 ± 0.10 | 11.72 ± 0.05 | 7.50 ± 0.10 |
| 10 | D2 | 192.74 ± 0.10 | 9.71 ± 0.10 | 10.00 ± 0.05 |
| 11 | D3 | 190.74 ± 0.10 | 12.17 ± 0.10 | 10.00 ± 0.15 |
| 12 | D4 | 174.61 ± 0.05 | 12.23 ± 0.10 | 15.00 ± 0.05 |
| 13 | D5 | 191.44 ± 0.15 | 12.90 ± 0.10 | 7.50 ± 0.15 |
| 14 | D6 | 192.14 ± 0.10 | 10.94 ± 0.10 | 10.00 ± 0.05 |
| 15 | E1 | 174.61 ± 0.15 | 11.84 ± 0.15 | 12.50 ± 0.10 |
| 16 | E2 | 191.44 ± 0.05 | 12.96 ± 0.05 | 10.00 ± 0.05 |
| 17 | E3 | 188.64 ± 0.05 | 11.67 ± 0.10 | 7.50 ± 0.10 |
| 18 | E4 | 190.04 ± 0.05 | 9.99 ± 0.10 | 7.50 ± 0.10 |
| 19 | E5 | 201.26 ± 0.05 | 8.64 ± 0.10 | 10.00 ± 0.15 |
| 20 | E6 | 183.03 ± 0.15 | 9.26 ± 0.15 | 10.00 ± 0.05 |
| Mean ± S.D | | 196.25 ± 12.33 | 10.66 ± 1.43 | 10.25 ± 2.55 |

Table 3: Recommended (Standards) Chemical Composition of Vegetable Oils by FAO/WHO (1993).

| S/N | Vegetable Oils | Saponification Value (mgKOH/g) | Acid Value (mgKOH/g) | Peroxide Value (meq/Kg) |
|-----|-----------------|-----------------------------------|-------------------------|----------------------------|
| 1 | Palm oil | 190 - 209 | ≤ 10 | ≤ 10 |
| 2 | Groundnut oil | 187 - 196 | ≤ 0.6 | ≤ 10 |
| 3 | Coconut oil | 248 - 265 | ND | ≤ 10 |
| 4 | Grapeseed oil | 188 - 194 | ND | ≤ 10 |
| 5 | Soyabean oil | 189 - 195 | ≤ 0.6 | ≤ 10 |
| 6 | Cottonseed oil | 189 - 198 | ≤ 0.6 | ≤ 10 |
| 7 | Sunflower oil | 183 - 194 | ≤ 0.6 | ≤ 10 |
| 8 | Palm kernel oil | 230 - 254 | ND | ≤ 10 |

Table 4: Recommended (Standards) Chemical Composition of Edible Oils as specified by NIS (1992).

| Saponification Value (mgKOH/g) | Acid Value (mgKOH/g) | Peroxide Value (meq/Kg) |
|-------------------------------------|-------------------------|----------------------------|
| 245 - 255 (Depending on the oil) | 0.6 Maximum | 10 Maximum |

The chemical properties of the palm oil samples, and their recommended standards are in tables 2 and 3 respectively. Saponification is an indicator of the molecular weight of triacylglycerols (TAGS) of oils. This value gives an index of the average fatty acid chain length present in the test oil [24]. High Saponification Value indicates a high proportion of low fatty acids. Since saponification value is inversely proportional to the average molecular weight [18]. The saponification value for the branded palm oil samples (A and B) were two 215.28mgKOH/g and

210.38mgKOH/g which is relatively higher than the [3] and [22] standards. The high saponification values may be due to the presence of local additives or adulterants as reported by [16].

However, the saponification values for the unbranded palm oil samples from new market with sample labels C1, C2, C3, C4 C5 and C6 are 206.87mgKOH/g, 211.08mgKOH/g, 193.55mgKOH/g, 220.89mgKOH/g, 199.86mgKOH/g and 201.26mgKOH/g respectively. These saponification values are within the recommended standard (except C2 and C4 which are higher) and are in accordance with the findings of [20] that saponification value within the range of 195.76 - 198.75mgKOH/g is of good quality and show no evidence of adulteration. The saponification values of C2 and C4 are higher than the recommended standard for palm oil but fall within the range of standard for palm kernel oil [3][22].

This result showed that the high saponification value might be a result of the presence of trace amount of palm kernel oil in the oil samples and since both oils are from the same plant and have almost the same color, there is possibility of adulteration or contamination without being noticed. This result is in accordance with [16] findings that adulteration or contamination has the potential of increasing the saponification value of Palm oil. Also, the unbranded palm oil samples from Oke-aje market with sample labels D1, D2, D3, D4, D5 and D6 had saponification values of 194.95mgKOH/g, 192.74mgKOH/g, 190.74mgKOH/g, 174.61mgKOH/g, 191.44mgKOH/g and 192.14mgKOH/g respectively, while palm oil samples from Itale market with samples label E1, E2,

E3, E4, E5 and E6 had saponification values (SV) 174.61mgKOH/g, 191.44mgKOH/g, 188.64mgKOH/g, 190.04mgKOH/g, 201.26mgKOH/g and 183.03mgKOH/g Respectively.

These values were within the SON/NIS recommended standard and the result is similar to those obtained by [21] palm oils with saponification values from 129.44 - 198.03mgKOH/g are not contaminated or adulterated and are therefore suitable for domestic and industrial applications as well as export trade. Acid value (AV) is a measure of the free fatty acid in oils. The higher the acid value, the higher the free fatty acid which also means decreased oil quality. The acid values for the branded palm oil samples with sample labels A and B were 8.81mgKOH/g and 9.79mgKOH/g respectively, while the acid values of the unbranded palm oil samples from new market with sample labels C1, C2, C3, C4 C5 and C6 were 10.04mgKOH/g, 11.05mgKOH/g, 9.26mgKOH/g, 9.37mgKOH/g, 9.59mgKOH/g and 12.01mgKOH/g respectively. Also, acid values of the unbranded palm oil samples from Oke-aje market with sample labels D1, D2, D3, D4, D5 and D6 were 11.72mgKOH/g, 9.71mgKOH/g, 12.17mgKOH/g, 12.23mgKOH/g, 12.90mgKOH/g and 10.94mgKOH/g respectively, while that of Itale market with sample labels E1, E2, E3, E4, E5 and E6 are 11.84mgKOH/g, 12.96mgKOH/g, 11.67mgKOH/g, 9.99mgKOH/g, 8.64mgKOH/g and 9.26mgKOH/g respectively.

The acid values were higher than [3] recommended standard but are within the recommended standard by [25], except for C2, C6, D1, D3, D4, D5, E1, E2 and E3, and are in line with [23] finding that acid value of 12.06 + 0.04mgKOH/g or above indicates high free fatty acid and leads to a

tendency to become rancid (that is off flavor). The deviation observed in the acid values of the aforementioned exceptions can be due to the various factors which include, presence of moisture in the oils, as these oils were produced locally and without adequate precautions or under standard conditions. The high acid value may also be because of elevated temperature [6]. It can be observed that these exceptions are unbranded palm oils that are exposed to sunlight on daily basis during sales. Long exposure of these oils to the sun or heat can increase the acid value, thereby making the oil susceptible to rancidity.

The peroxide value determines the degree of oil oxidation. It is a useful indicator of the early stage of rancidity occurring under mild conditions [22]. The peroxide value of the palm oil samples with sample labels A, B, C1, C2, C4, D1, D2, D3, D5, D6, E2, E3, E4, E5 and E6 range between 7.50 - 10.00meq/Kg. These values were closely related to the standard value of 10meq/Kg recommended by [3], [4] and [25]. However, higher peroxide value was obtained for C3, C5, C6, D4 and E1 (12.50 - 15.00meq/Kg). This value indicates the onsets of primary oxidation due to lipid degrading enzymes like peroxidase and lipoxygenase [22]. At this level, the rancid taste might not be noticeable since they are below the peroxide value of 20 - 40meq/Kg [11]. The results were also comparable with those obtained by [16] findings that adulteration of palm oils with red dye reduces the peroxide value of the palm oil to 12.00meq/Kg which is much lower than the SON/NIS standard, but higher than the results obtained by [20] and [21] that peroxide value from 7.80 - 8.40meq/Kg is of good quality and shows no evidence of adulteration.

CONCLUSIONS AND RECOMMENDATIONS

The quality of Palm oil is mostly determined by the chemical constituents which are saponification, acid and peroxide values. Any increase or decrease in the value of these parameters from the recommended standard can relatively be used as an index of adulteration or deterioration of the palm oil. The results obtained from this study showed that the saponification values, acid values and peroxide values of the palm oil samples investigative were within the standard recommended by [3] and [22] and were also comparable with the results of past findings of [16][21] and [20], with only a few exceptions which may have occurred due to difference in storage factors or handling. Since measurements of common quality parameters of fat and oil may not be helpful in identifying palm oil adulteration with red dye, it cannot, therefore, be ascertained that the palm oil samples investigated show no evidence of adulteration. The results obtained, however, indicated that palm oil samples from New-market and the branded palm oil samples had greater industrial values (for soap production) than palm oils from Oke-Aje and Itale markets. This is as a result of their higher saponification values which showed the suitability of the oils for soap production. However, samples from Itale market and Okey-aje market and the branded palm oil samples may have higher shelf-life (due to their low peroxide values) than the palm oil samples from New-market because of the observed high peroxide value in the oils from these markets.

In conclusion, palm oils from Ijebu-Ode have a good shelf-life and are suitable for both domestic and industrial applications.

It has been understood that the quality of palm oil is a very important issue in food chemistry. This research is proven to support existing knowledge on the chemical composition of Crude Palm Oil and will aid future researchers, as they will be able to leverage the findings of this research to make informed hypotheses in the future. The school curriculum is in a dynamic state, it calls for continuous content updates.

On the basis of these findings, the following recommendations were made:

- i. Update of school curriculum to reflect storage and packaging materials as factors that affect the composition/quality of Crude Palm Oil.
- ii. Universities in conjunction with the quality assurance agency should set up an informal information session with the accreditation process for Local palm oil retailers to educate them on better and more effective methods of handling and storing their palm oils.
- iii. At the formal level of education, secondary school students should be educated on the usability of Crude palm oils based on their chemical composition. The food chemistry aspect of their science curriculum school is designed in such a way that they are well informed on which palm oil is suitable for domestic or industrial applications.
- iv. Local palm oil producers should be given grants in form of business loans to encourage their output because their product seems to be industrially better than branded palm oils.

Furthermore, college students seeking to conduct their thesis in a related field would find this article informative enough for their literature review. [26] reported that Fourier Transfer Infrared (FTIR) Spectroscopy is accurate and precise enough for rapid analysis of lard in palm oil. [27] also discovered that differential scanning calorimetry (DSC) can distinctly identify refined, bleached and deodorized palm oil samples adulterated with different animal body fats. [28] discovered in his finding that, measurement of common quality parameters of fats and oils may not help identify palm oil adulterated with red dye and further suggest that evaluation of sensory attributes, particularly color, taste and mouthfeel, can be considered a reliable approach.

REFERENCES

1. AOAC International (2005): Official methods of analysis of AOAC international, 18th ed. USA: AOAC International. 2005.
2. Pearson, D. 1981. The chemical analysis of foods. Churchill Living Stone. Edinburgh. London. 150pp.
3. SON. (2000). Standards for edible refined palm oil and its processed form. Standard Organization of Nigeria, 1: 2-5pp.
4. NIS. (1992). Standard for edible vegetable oil. Nigerian Industrial Standards 4(2):5-12.
5. Gunstone F. D. (2005). Vegetable Oils. In F. Shahidi (Ed.). Bailey's Industrial Oil and Fat Products (pp. 213-267). 6th ed., Vol. 5., John Wiley & Sons, Inc.
6. Rajko V, Sergeja V, Helena A (2010). Biochemical parameters and oxidative resistance to thermal treatment of refined and unrefined vegetable edible oils. Czech J. Food Sci. 28: 376-384.
7. Rukmini, C (1994). Red Palm Oil to Combat Vitamin A deficiency in Developing Countries. In Food and Nutrition Bulletin Vol. 15 (1993/1994), Number 2, June 1994. United Nations University Press.
8. May Y. C. (1994). Palm oil carotenoids. Food and Nutrition Bulletin, 15 (2): 58-71.

9. Elena, A A; Parker, L (1994). Antioxidant and Biological Activities of Palm Oil Vitamin E. In Food and Nutrition Bulletin Vol. 15 (1993/1994), Number 2, June 1994. United Nations University Press.
10. Gee, P.T. (2007). Analytical characteristics of crude and refined palm oil and fractions (A review). *Eur. J. Lipid Sci. Technol.*, 109: 373–379.
11. Kirk, R.S. and R. Sawyer, 1991. Oils and Fats. In: Composition and Analysis of Food, Kirk, R.S. and R. Sawyer (Eds.). 9th Edn., Longman Scientific and Technical, London.
12. Okogeri, O. and Okoro, B. (2014). Storage stability and sensory attributes of crude palm oil adulterated with red dye. *European Journal of Agriculture and Forestry Research*, 2(1): 10-17.
13. Peng, He., Xiaoqing, W., Chenglin, W. and Yingpu J. (2014). Determination of animal oil added in vegetable oil by standard chemical method coupled with image texture analysis technology. *International Journal Innovative Computing, Information and Control*, (10): 319-332.
14. Tagoe, S. M., Dickinson, M. J. and Apetorgbor, M. M. (2012). Factors influencing quality of palm oil produced at the cottage industry level in Ghana, *International Food Research Journal*, 19 (1): 271-278.
15. Salunkhe D K, Chavan R W, Kadam, S S. (1992). World Oil Seed, Chemistry Technology and Utilization, An AVI Book Published by Van Nostrand Reinhold, New York pp. 148–192.
16. Ekop, S. A., Etuk, B. A. and Eddy, N. O. (2007). Effect of some local additives on the chemical constituent of palm oil. *Journal of Applied Science and Environment*, 11 (1): 85 - 89.
17. Gur, M.I. and J.L. Harwood, 1991. *Lipid Biochemistry: An Introduction*. Chapman and Hall, London, pp: 406.
18. Muhammad, N., Bamishaiye, E., Bamishaiye, O., Usman, L., Salawu, M., Nafiu, M. and Oloyede, O. (2011). Physicochemical properties and fatty acid composition of *Cyperus Esculentus* (Tiger Nut) Tuber oil. *Bioresources Bulletin*, 5: 51-54.
19. Akinhanmi TF, Atasi VN (2008). Chemical composition and physicochemical properties of cashew nut (*Anacardium occidentale*) Oil and Cashew nut Shell Liquid. *J. Agric. Food Environ. Sci.* 2: 1-10.
20. Agbaire, P. O. (2012). Quality assessment of palm oil sold in some major markets in Delta State, Southern Nigeria. *African Journal of Food Science and Technology*, 3(9): 223-226.
21. Udensi, E. A. and Iroegbu, F. C. (2007). Quality assessment of palm oil sold in major markets in Abia State, Nigeria. *Journal of Agro-Science*, 6(2): 25-27.

22. Onyeka E. U., Onugbu, N. L, Onuoha, N. U. and Ochonogor F. (2005). Effect of extraction pretreatment on the composition and characteristics of seed and pulp oil of African black pear (*Dacryodesedulis*). *Nigerian Food Journal*, (23): 13-20.
23. Tamzid H. M., Alam, M. T. and Islam, M. (2007). Physico-chemical and nutritional studies of *Terminalia Belerica* Roxb. seed oil and seed kernel. *Journal of Biological Sciences*, (15): 117-126.
24. Osahon K. Ogbiede, Ephraim A. Omorotionmwan, Osakpolor D. Igenumah, Hilary I. Ifijen & Isaac U. Akhigbe (2022). Comparative Analysis on Physicochemical Properties and Chemical Composition of Coconut and Palm Kernel Oils. *ChemSearch Journal* 13(1): 70 – 75 <https://www.ajol.info/index.php/csj/article/view/229420>.
25. C.A.C. (2001). Codex standard for named vegetable oils. Codex-Stan 210 Volume 8, Codex Alimentarius Commission, Geneva. Switzerland. 16pp.
26. Rohman, A., Kuwat, T., Retno, S., Sisindari, Yuny, E. and Tridjoko. W. (2012). Fourier transform infrared spectroscopy applied for analysis of lard in palm oil. *International Food Research Journal*, 19(3):1161-1165.
27. J. M. N. Marikkar, O. M. Lai, H. M. Ghazali & Y. B. Che Man (2001). Detection of lard and randomized lard as adulterants in refined-bleached-deodorized palm oil by differential scanning calorimetry. *Journal of the American Oil Chemists' Society*. <https://doi.org/10.1007/s11746-001-0398-5>.
28. Okogeri, O. (2013). Adulteration of crude palm oil with red dye from the leaf sheath of sorghum bicolor. *Food Science and Quality Management*, (17): 2224-6088.

ANALYSIS OF CONTENT ALIGNMENTS BETWEEN THE NEW GRADE 7 GENERAL SCIENCE TEXTBOOK AND THE RESPECTIVE SYLLABUS

Eshetu Desalegn Alemneh* and Solomon Melesse Mengistie**

* DEd Candidate in Chemistry at College of Science, Bahir Dar University, Ethiopia

** Department of Teacher Education and Curriculum Studies, College of Education, Bahir Dar University, Ethiopia

Corresponding Author Email: eshetu1976@gmail.com

ABSTRACT

The purpose of this study was to check the alignment between the new grade seven general science textbook prepared by the Amhara National Regional State Education Bureau (ANRSEB) and the respective national syllabus. To this end, purposive sampling and quantitative research approaches were used to see the alignments of students learning outcomes (SLOs), contents, and levels of cognitive development between the syllabus and the textbook. In addition, the distribution of the level of cognitive development was also checked. Checklists and rubrics were used as data collecting tools. The findings revealed that 79.22% of the SLOs were perfectly aligned, 3.9% were partially aligned and 16.88% were not aligned. In terms of content alignments, 88.46% were aligned, 7.69% were partially aligned and 3.82% were not aligned. In relation to levels of cognitive development, the overall alignment index (P) was 0.914. Results related to the distribution of level of cognitive development indicated that 89.47% were entertaining lower-order thinking and 10.53% were higher-order thinking. So, it is possible to conclude that the textbook has acceptable alignment with the respective syllabus, but it lacks perfect alignment. On this background, it is recommended that the textbook should be revised to make it perfectly aligned with the syllabus as well as to entertain higher-order thinking skills so that its users could satisfy the 21st c. skills. [*African Journal of Chemical Education—AJCE 13(1), January 2023*]

INTRODUCTION

Background of the Study

Education enables individuals and society to make all-rounded participation in the development process by acquiring and enriching knowledge, skills, and attitudes. Education teaches us how to think, how to work properly, and how to make a decision; in general, it teaches us how to lead a successful and meaningful life [1]. Science education is the one that fosters students' curiosity about the world, develops problem-solving skills, and enhances scientific thinking.

Every nation has its own national goals and aims which are prepared in the form of curricular element documents [2]. In developing countries, the quality of education exclusively depends on these curricular elements particularly the syllabus and the textbooks prepared for the learners. Appropriately designed aims and goals at the national level lead to the golden opportunity to have standardized textbooks [3]. Syllabus-textbook alignment takes to be a great concern to put into practice the national aims and goals. Textbooks are developed in such a way that the learning outcomes, pedagogical approach, contents, activities, and designed assessments presented in the textbooks are aligned with the syllabus. If there is no textbooks - syllabus alignment, it is difficult to achieve national goals to the desired extent which badly affects the quality of the education systems [2, 3].

Textbook is considered the backbone of the educational system because it plays an important role in instruction as it is the most used and easily available source of knowledge in the country. For

many teachers, the textbook is used to guide them in delivering their contents in the classroom. As for learners, the textbook serves as a framework to help them in organizing their learning both inside and outside the classroom [4]. Studies showed that students' learning is directly affected by the quality of textbooks, and they struggle with the textbook in that field because they can't learn anything from the textbook that they can't read [5, 6]. In line with its importance, they must align with the syllabus to enhance students' learning outcomes [7].

The alignments of textbook-syllabus ensure alignment of goals and objectives, instructions, and assessments. Therefore, the development of textbooks aligned with the syllabus is considered one of the basic steps in the implementation of the curriculum [8]. According to Bhatti, Jumani [9], a lack of proper alignment between textbook and syllabus will lead the teachers' instruction into other objectives other than the suggested objectives in the syllabus and this gap reflects a lack of coordination between syllabus developers and textbook writers.

Ethiopia is one of the developing countries in which the education system is being declined. The poor education system may arise from different corners (like the economical deficit, lack of skilled curriculum experts, lack of standardized available teaching materials, the mismatch between the teaching materials and the national aims, goals, and the like). Among the standardized teaching materials, textbooks take the lion's share of the system.

Currently, Ethiopia has introduced a new general educational roadmap. Due to the new roadmap, new textbooks have been prepared and they are under piloting in the current education

year (2021/22). Secondary school (Grades 9- 12) textbooks are prepared by the ministry of education (MoE) at the national level and elementary and middle school textbooks are prepared by the respective regional education bureaus. Among the different textbooks, the grade 7 general science textbook is one of the middle school textbooks prepared by the respective regions.

This study was an endeavor for investigating how many of the contents, learning outcome, and the designed level of cognitive development of the textbook, is aligned with the syllabus. The study also intended to check the inclusion of all the levels of development in the Bloom's cognitive domains. This newly prepared textbook is now being piloted; at this piloting stage conducting alignment analysis is very important to enhance the quality of the textbook. This was the reason why the researcher intended to do this alignment analysis study based on the alignments of the new Grade 7 general science textbook prepared by ANRSEB with the respective national syllabus prepared by MoE.

Statements of the problem

The curricular documents are considered to be the road map for the attainment of the national aims and goals and there is a need for perfect alignment among the different curricular materials. Among the different alignments, textbook-syllabus alignment is the decisive factor for the achievement of the national goals and aims [10, 11]. For this purpose, textbooks should be developed in such a way that their contents are aligned with the syllabus document. If there is no

alignment between the textbooks and syllabus, it is not possible to achieve national aims and goals to the desired extent, and badly affects the whole system of education [12]. The grade seven general science textbook is one of the newly prepared curriculum materials in ANRSEB and as a new textbook, there is a need of checking its alignment with the national syllabus. To check this, there is a need for alignment analysis [13].

Therefore, this research was conducted quantitatively to check the alignments of the new Grade 7 General Science textbook prepared by ANRSEB and the respective syllabus prepared by MoE of Ethiopia using the following research questions:

- How much the SLOs in the textbook aligned with the SLOs in the syllabus?
- To what extent do the contents and sub-contents in the textbook align with the syllabus?
- Does the cognitive development level in the textbook aligned with the respective syllabus?
- To what extent cognitive development levels accommodate higher-order thinking in both curriculum materials?

Objectives of the study

The general objective of the study was to examine the general alignments of the new grade 7 general science textbook which was prepared by the Amhara regional state with the respective national syllabus.

This alignment analysis research aimed to meet the following specific objectives:

- To see the alignment SLOs between the national syllabus and the grade seven general science textbook prepared by ANRSEB.
- To check the alignments of contents and sub-contents stated in the national syllabus and the new grade seven general science textbook prepared by ANRSEB.
- To check the cognitive development levels alignment between the new grade seven general science textbook prepared by ANRSEB with the national syllabus.
- To examine whether both curriculum materials promote higher-order thinking skills or not.

Operational Definitions

Alignment: Is the agreement between the grade 7 general science textbook prepared by ANRSEB and the national syllabus prepared by MoE of Ethiopia (2021).

Textbook: In this research, the textbook refers to grade 7 general science students' textbooks prepared by Amhara regional state in 2021.

Syllabus: National curriculum elements document which specifically indicates the outline description of grade 7 general science subjects.

Levels of cognitive development: It exclusively reflects the Bloom's cognitive taxonomy.

Conceptual Framework of the Study

The Ethiopian grade seven general science syllabus prepared in 2021 is a comprehensive document suggesting the benchmarks, themes, students' learning outcomes, and guidance for textbook development, assessment, and instructional strategies. The content consists of seven broad categories which are marked as chapters. The first chapter deals with basic science, the second and third chapters deal with chemistry, the fourth and fifth chapters deal with biology, and the last two chapters deal with physics. An important feature of the national Curriculum 2021 for general science for middle primary classes is that it outlines realistic, observable, achievable, and measurable students' learning outcomes. The rationale for the emergence of the 2021 curriculum is due to the different drawbacks of the older curriculum did not entertain the 21st-century needs of educational skills such as critical thinking, problem-solving, global and cultural awareness, digital literacy, oral and written communication, creativity, collaboration, decision making, developments of higher order thinking. To alleviate these shortcomings, a new curriculum framework and syllabus have been developed [14].

Alignment analysis involves observation and document analysis and indicated the analysis of what is contained in a message. Krippendorff [13] defined content analysis as a research technique for making replicable and valid inferences from the data to their context.

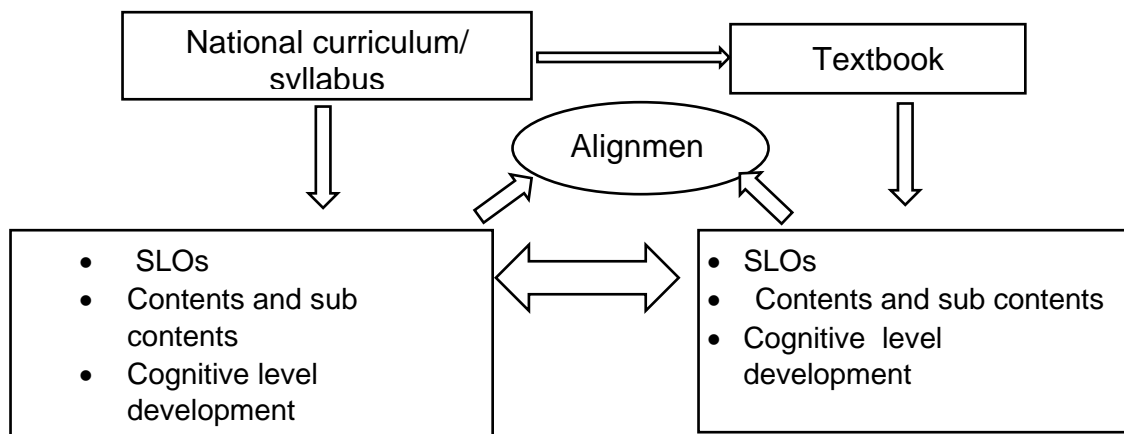


Figure 1: Conceptual Framework of the Study

METHODOLOGY

The research design was descriptive content analysis in nature and was mainly conducted through observational document analysis and survey of enacted curriculum (SEC) protocol which were adapted from scholars such as SAEED and RASHID [2] and Porter [15] .

A purposive sampling technique was used to select the textbook because of the accessibility of the textbook and the researchers' proximity to the science subjects and the textbook is now being piloted.

The data were collected through document analysis using a checklist for content–syllabus alignment and rubrics content-syllabus alignment level of cognitive development/domain of Bloom’s Taxonomy.

National syllabus of general science grade 7(2021) MoE and Grade 7 general science textbook prepared by ANRSEB were used as data source documents.

The data were analyzed quantitatively, in this case, the SLOs and the contents alignments displayed with percentages and cognitive level development were analyzed and presented using Porter [15] alignment formula. Moreover, to evaluate the strength of alignment, Fulmer [16] table of critical values was employed. According to Fulmer's critical value, an alignment index less than 0.5 is very weak, 0.5-0.7 is weak, ≥ 0.7 is acceptable and 1 indicates perfect alignment.

DATA PRESENTATION, ANALYSIS, AND DISCUSSION

In this section, the collected data were presented, analyzed, and interpreted quantitatively. They were presented with graphs and tables and interpreted with percentages and Porter’s alignment index.

Presenting and Analyzing the Alignments of Students Learning Outcomes (SLOs)

The alignments of students learning outcomes given at the start of each chapter in the Grade 7 General Science students' Textbook prepared by ANRSEB and the national syllabus were analyzed and displayed in the following tables.

Table 2: Analysis of Alignments of Students Learning Outcomes (SLOs) Given in Chapter One

| SLOs stated in the textbook | SLOs stated in the syllabus | Degree of alignment | | |
|--|---|---------------------|---------|-----|
| | | Perfect | Partial | Not |
| Explain the nature of science. | Define science as a body of knowledge, the processes, and practices | √ | | |
| Describe the main branches of science | Describe the main branches of science | √ | | |
| Explain the difference between science and technology | Describe the difference between science and technology | √ | | |
| Explain how technology and science affect human behavior, practice, and ways of thinking | Relate how science and technology affect one's beliefs, practices, and ways of thinking | √ | | |
| Appreciate the contributions of famous scientists of Ethiopia to science and technology | Appreciate the contributions of outstanding scientists to science and technology | √ | | |
| Identify basic and derived units of measurements | | | | √ |
| Explain the concept of measuring physical quantities | | | | √ |
| Explain the difference between scalar, vector physical quantities, fundamental and derived physical quantities | | | | √ |
| Identify different laboratory tools | Identify different laboratory tools | √ | | |
| Demonstrate safe ways of using apparatus in the laboratory | Demonstrate safe ways of using apparatus in the laboratory | √ | | |
| Practice precautionary measures in the laboratory | Practice precautionary measures in the laboratory | √ | | |
| Apply laboratory safety rules and procedures | Exhibit knowledge of lab safety rules and procedures | √ | | |
| Identify potential hazards and implement appropriate safety procedures when conducting laboratory experiments | Identify potential hazards and implement appropriate safety procedures when working in the laboratory | √ | | |
| 13 | 10 | 10 | | 3 |

As vividly indicated in Table 1, the students learning outcomes described in chapter one of the textbook are moderately aligned with the national syllabus developed by Ethiopian MoE (2021). In the textbook, there are thirteen main SLOs described in the first chapter, among these, ten of them (76.92%) were perfectly aligned and three of them (23.08%) were not aligned with the syllabus.

Table 3: Analysis of Students Learning Outcomes SLOs Given in Chapter Two

| SLO in the textbook | SLO described in the syllabus | Degree of alignment | | |
|--|--|---------------------|---------|-----|
| | | perfect | Partial | Not |
| Use particle theory's postulates to explain the properties and behavior of materials. | Use particles theory's postulates to explain the properties and behavior of materials | √ | | |
| Classify matter as an element, compound, homogeneous mixture, or heterogeneous mixture concerning physical properties. | Classify matter as an element, compound, homogeneous or heterogeneous mixtures concerning its physical properties | √ | | |
| Describe the structure of solids, liquids, and gases in terms of particle separation, arrangement and types of motion | Describe the structure of solids, liquids, and gases in terms of particle separation, arrangement, and types of motion | √ | | |
| Differentiate between physical and chemical properties and changes of matter. | Differentiate between physical and chemical properties and changes in matter | √ | | |
| Appreciate that matter can be classified based on physical or chemical properties | Appreciate that matter can be classified based on physical or chemical properties | √ | | |
| Use properties of matter to identify substances and separate them | Use properties of matter to identify substances and separate them | √ | | |
| Demonstrate scientific inquiry skills in this unit: inferring, observing communicating, asking questions, classifying, comparing and contrasting, making models, designing experiments, drawing conclusions, and applying concepts | Demonstrate scientific inquiry skills along this unit: observing, classifying, comparing and contrasting, making mode, inferring, communicating, asking questions, designing experiments, drawing conclusions, applying concepts | √ | | |
| 7 | 7 | 7 | | |

As vividly indicated in Table 2, all the SLOs described in chapter two of the textbook are perfectly aligned with the national syllabus.

Table 4: Analysis of Students Learning Outcomes (SLOs) Given in Chapter Three

| SLO in the textbook | SLO described in the syllabus | Degree of alignment | | |
|---|---|---------------------|-----------|-----|
| | | perfect | Partially | Not |
| Compare elements to compounds and how they are represented by symbols and formulae | Compare elements to compounds and how they are represented by symbols and formulae | √ | | |
| write symbols of common elements or compounds | Identify and write symbols of common elements or compounds. | √ | | |
| Name compounds given their formula and write the formula given the name of the compound | Name compounds given their formula and write the formula given the name of the compound. | √ | | |
| Use symbols and chemical formulae as a way of communicating information about elements and compounds. | Use symbols and chemical formulae as a way of communicating information about elements and compounds. | √ | | |
| State and apply the Law of Mass conservation to writing balanced equations | State and apply the Law of Mass conservation to writing balanced equations | √ | | |
| Interpret chemical formulae of compounds in terms of the elements present and the ratios of their atoms | Interpret chemical formulae of compounds in terms of the elements present and the ratios of their atoms | √ | | |
| 6 | 6 | 6 | | |

As brightly indicated in Table 3, all the SLOs described in chapter three are stated in the national syllabus. These indicated the perfect alignment of SLOs for the third chapter.

Table 5: Analysis of Students Learning Outcomes (SLOs) Given in Chapter Four

| SLO in the textbook | SLO described in the syllabus | Degree of alignment | | |
|---|---|---------------------|------|-----|
| | | perfect | Part | Not |
| | | | ial | |
| Define a microscope | Define a microscope | √ | | |
| Explain the use of a microscope | Explain the use of a microscope | √ | | |
| Distinguish the different types of microscopes | Distinguish the different types of microscopes | √ | | |
| Describe the basic parts and functions of a microscope • | Describe the basic parts and functions of a microscope | √ | | |
| Use a microscope to observe objects | Use a microscope to view objects | √ | | |
| Define a cell | Define a cell | √ | | |
| Explain how the cell was discovered • | Explain how the cell was discovered and who discovered it | √ | | |
| Draw a cell and label its major parts | Draw a cell and label its major parts | √ | | |
| Describe the functions of the major structural parts of a cell | Describe the functions of the major structural parts of a cell | √ | | |
| Distinguish between unicellular and multicellular organisms • | Distinguish between unicellular and multicellular organisms | √ | | |
| Give examples of cell shape | Give examples of cell shape | √ | | |
| Explain why cell shape and structure vary • | Explain why cell shape and structure vary | √ | | |
| Discuss the differences between cell, tissue, organ, and organ system | Discuss the differences between cell, tissue, organ, and organ system | √ | | |
| Define respiration and write its chemical equation • | Define respiration and write its chemical equation | √ | | |

| | | |
|--|---|----|
| Describe photosynthesis and its chemical equation • | Define photosynthesis and write its chemical equation | ✓ |
| Develop scientific thinking and inquiry skills • | | ✓ |
| Develop and use a model to describe the structure and function of a cell. • | | ✓ |
| Analyze and describe the relationships of the hierarchical levels in the classification of organisms | | ✓ |
| 18 | 15 | 15 |
| | | 3 |

As Table 4 indicated, the SLOs described in chapter four of the textbook had acceptable alignment with the national syllabus. In the syllabus, there are fifteen main SLOs described in the fourth chapter whereas there are eighteen SLOs in the textbook. Among these fifteen of them (83.33%) were aligned and three of them (16.67%) were not stated in the syllabus.

Table 6: Analysis of Students Learning Outcomes (SLOs) Given in Chapter Five

| SLO in the textbook | SLO described in the syllabus | Degree of alignment | | |
|---|--|---------------------|---------------|-----|
| | | perfect | Partiall y | Not |
| Distinguish between living and nonliving things by describing the features that characterize living organisms • | Distinguish between living and non-living things by describing the features that characterize living organisms | ✓ | | |
| Discuss if movement i.e. locomotion can characterize all living things or not | Discuss if movement i.e. locomotion can characterize all living things or not | ✓ | | |
| Define classification and its purpose | Define classification and its purpose | ✓ | | |
| Explain the purpose of the scientific name | Explain the purpose of the scientific name | ✓ | | |

| | | | |
|---|---|---|---|
| List down the hierarchical levels in the classification of organisms | List down the hierarchical levels in the classification of organisms | ✓ | |
| Describe the distinguishing characteristics of the kingdom Animalia, Plantae, Protista, Monera, and Fungi • | Describe the distinguishing characteristics of the kingdom Animalia, Plantae, Protista, Monera, and Fungi | ✓ | |
| List common examples of animals, Plantae, Protista, Monera, and Fungi • | List common examples of animals, Plantae, Protista, Monera, and Fungi | ✓ | |
| Describe the body plan of common animals, Plantae, Protista, Monera, and Fungi • | Describe the body plan of common animals, Plantae, Protista, Monera, and Fungi | ✓ | |
| Describe habitats of animals, Plantae, Protista, Monera, and Fungi | Describe habitats of animals, Plantae, Protista, Monera, and Fungi | ✓ | |
| Compare the five kingdoms of living things by describing their distinguishing characteristics | | ✓ | |
| Summarize the commonest examples of organisms belonging to each Kingdom. | | ✓ | |
| Describe the body plans of insects such as butterflies, amphibians such as frogs, mosses, liverworts, ferns, conifers such as junipers, flowering plants, Paramecium, Algae, and Mushroom | | ✓ | |
| Relate each Kingdom of organisms to their major habitat types as aquatic, terrestrial, or moist | | ✓ | |
| 13 | 9 | 9 | 4 |

As vividly indicated in Table 5, among the thirteen SLOs in the textbook only 9(69.23%) are perfectly aligned and 4 (30.77%) are not aligned with the national syllabus in the fifth chapter.

Table 6: Analysis of Students Learning Outcomes (SLOs) Given in Chapter Six

| SLO in the textbook | SLO described in the syllabus | Degree of alignment | | |
|---|---|---------------------|-----------|-----|
| | | perfect | Partially | Not |
| Describe the shape of the earth | Describe the shape of the earth | √ | | |
| Identify the evidence supporting the shape of the earth • | Identify evidence supporting the shape of the earth | √ | | |
| | List local and global ideas about the shape of the earth | | | √ |
| • Name dimensions (circumferences, diameters, and angular distances) of the earth | Name dimensions (circumferences, diameters, and angular distances) of the earth | √ | | |
| • | Recognize all parts of the earth | | | √ |
| Describe the organization and contents of the parts of the earth • | Describe the organization and contents of the different parts of the earth | √ | | |
| Differentiate between rotation and revolution of the earth | Demonstrate movements of the earth (revolution and rotation) | √ | | |
| Describe the interaction between the hydrosphere, biosphere, atmospheric, and lithosphere • | Explain different observations about the earth in terms of the nature and behaviors of the parts of the earth | | √ | |
| Explain effects of motions of earth • | Explain effects of motions of the earth | √ | | |
| Construct a model of the earth | Construct model of earth and use it to explain phenomena related to its motion | √ | | |
| Develop science process skills | Identify atmospheric and lithospheric systems | | | √ |
| Explain water and carbon cycles on earth's spheres | Explain their cycle effects on the earth | | √ | |
| | Describe the measuring techniques for too-big (Earth) and too-small (continental drift) quantities measurement and estimation | | | √ |
| 10 | 13 | 7 | 2 | 4 |

As shown in Table 6, there are thirteen SLOs in the syllabus, among these, 7 (53.85%) were perfectly aligned, 2 (15.38%) were partially aligned, and 4(78%) were not aligned with the textbook for the sixth chapter.

Table 7: Analysis of Students Learning Outcomes (SLOs) Given in Chapter Seven

| SLO in the textbook | SLO described in the syllabus | Degree of alignment | | |
|---|---|---------------------|-----------|-----|
| | | Perfect | Partially | Not |
| Describe the terms motion, force, work, and energy • | Describe the term motion and the term force | √ | | |
| Explain the various types of motion | Identify types of motion (motion on a straight line, circular motion, rotary motion, and curvilinear motion) | √ | | |
| Develop the skill of manipulating numerical problems related to motion, force, and energy • | Show those types of motion in the class. | √ | | |
| Analyze data to identify patterns or relationships • | | | | √ |
| Explain the various effects of force | List all effects of force | | √ | |
| Appreciate how the concepts of force, motion work, and energy are related | Explain gravitational force | | | √ |
| Explain the real application of rectilinear & Newton's laws of motion | Demonstrate the pulling/pushing activity of force | √ | | |
| | Relate the effects of force with their daily life experience | | | √ |
| | Identify different measuring scales on measuring devices of force | | | √ |
| | Define energy as a property of matter that can be converted | | | √ |
| List different forms of energy | List all forms of energy | √ | | |
| Name parts of measuring device of force | Explain which energy is converted to other forms of energy. | | | √ |
| | List sources of energy | | | √ |

| | | | | |
|---|--|---|---|---|
| Differentiate between a renewable and non-renewable sources of energy | Distinguish between renewable and non-renewable forms of energy. | √ | | |
| Explain the conservation of energy | Describe how energy is used wisely. | √ | | |
| | List the strategies for the conservation of energy | | | √ |
| 11 | 16 | 7 | 1 | 8 |

As indicated in Table 7, there are 16 SLOs in the syllabus. Among these, 7 (43.75%) are perfectly stated, only 1 (6.25%) are partially stated, and 8 (50%) were not stated in the textbook for the seventh chapter.

Presenting and Analyzing the Alignments of Contents

In this section, the alignments of contents and sub-contents stated were analyzed between the national syllabus and the new grade seven general science textbook prepared by the Amhara National Regional state education bureau

Table 8: Analysis of Overall Contents Alignment

| Chapters | Contents in the Syllabus | Contents in the Textbook | Degree of alignment | | |
|----------|---|---|---------------------|---------|-----|
| | | | perfect | partial | Not |
| One | 1. Basic concepts of science | 1. Basic concepts of science | √ | | |
| | 1.1 The nature of science and its Branches | 1.1 Nature of science | √ | | |
| | 1.2 Scientific measurements | Branches of science | | | √ |
| | 1.3 Common laboratory equipment, uses, safety rules, and procedures in science laboratories | 1.2 Common laboratory equipment, uses, safety rules, and procedures in science laboratories | √ | | |
| Two | 2. Matter and our surrounding | 2. Matter in Our Surroundings | √ | | |

| | | | |
|-------|--|--|---|
| | 2.1 Characteristics and nature of matter | 2.1 Characteristics and nature of matter | √ |
| | 2.2 Physical and chemical properties of matter | 2.2 Physical and chemical properties of matter | √ |
| | 2.3 Classification of substances (in terms of composition and observable properties) | 2.3. Classification of substances with composition and Observable properties | √ |
| | 2.4 Changes Around Us: Physical and chemical changes | 2.4 Changes around Us: Physical and Chemical Change | √ |
| | 2.5 Separation of mixtures and their application periods | 2.5 Separation of mixtures and their application | √ |
| Three | 3. Elements, Compounds, and Chemical Reactions | 3. Elements, Compounds, and Chemical Reactions | √ |
| | 3.1. Elements and their representation | 3.1. Elements and their representation | √ |
| | 3.2 Compounds and their representation | 3.2. Compounds and their representation | √ |
| | 3.3 Simple chemical reactions and equations | 3.3 Simple Chemical reactions and Equations | √ |
| | 3.4 Uses Of Chemical Reactions in Every Day Situation | 3.4 Uses of Chemical reactions in an everyday situation | √ |
| Four | 4. Cell as a basis of life | 4. Cell as the Basis of Life | √ |
| | 4.1 Microscope | 4.1 Microscope | √ |
| | 4.1.1 history of the invention of the Microscope | 4.1.1 History of Invention of Microscope | √ |
| | 4.1.2. Types of microscope | 4.1.2 Types of microscope | √ |
| | 4.1.3. Basic parts of a compound microscope | 4.1.3 Basic Parts of Compound Microscope | √ |
| | 4.2 Cell | 4.2 Cell | √ |
| | 4.2.1 What is a cell? | 4.2.1 What is a cell? | √ |
| | 4.2.2. The discovery of cell | 4.2.2 The discovery of cell | √ |
| | 4.2.3. Structure of a cell | 4.2.3 Structure of a cell | √ |
| | 4.2.4. Cell shape and size | 4.2.4 Cell shape and size | √ |
| | 4.2.5. Multicellular organisms and multicellular organism | 4.2.5 Unicellular and multicellular organisms | √ |
| | 4.2.6. Cell, Tissue, Organ, and Organ system | 4.2.6 Cell, Tissue, Organ, Organ system, and organism | √ |

| | | | | | |
|-------|---|--|----|---|---|
| | 4.2.7. Respiration and Mitochondria | 4.2.7 Respiration and mitochondria | √ | | |
| | 4.2.8. Photosynthesis and Chloroplast | 4.2.8 Photosynthesis and chloroplast | √ | | |
| Five | 5. Living things and their diversity | 5. Living things and their diversity | √ | | |
| | 5.1 Living Things | 5.1 Living Things | √ | | |
| | 5.1.1. Characteristics of living things | 5.1.1 Characteristics of living things | √ | | |
| | 5.1.2. Classification and scientific names of organisms | 5.1.2 Classification and Scientific names of organisms | √ | | |
| | 5.1.3. Hierarchy in the classification of organisms | 5.1.3 Hierarchy of classification | √ | | |
| | 5.2. Kingdoms of Life | 5.2 Kingdoms of Life | √ | | |
| | 5.2.1. Kingdom Animalia | 5.2.1 Kingdom Animalia | √ | | |
| | 5.2.2. Kingdom Plantae | 5.2.2 Kingdom Plantae | √ | | |
| | 5.2.3. Kingdom Protista | 5.2.3 Kingdom Protista | √ | | |
| | 5.2.4. Kingdom Monera | 5.2.4 Kingdom Monera | √ | | |
| | 5.2.5. Kingdom Fungi | 5.2.5 Kingdom Fungi | √ | | |
| Six | 6. Earth in space | 6. The Earth | √ | | |
| | 6.1 Shape & Dimensions | 6.1 Shape and dimensions | √ | | |
| | 6.2 Parts of the Earth | 6.2 Parts of the earth | √ | | |
| | 6.3 Movements of the Earth | 6.3 Movements of the earth | √ | | |
| | 6.4 Earth's subsystems | 6.4 Earth's subsystems | √ | | |
| | 6.5 carbon and water Cycles | 6.5 Carbon and water cycles | | | |
| Seven | 7. Motion, Force, Energy, and energy resources | 7. Motion, Force, Energy, and Sources of Energy | √ | | |
| | 7.1 Definition of motion | 7.1 Definition and types of motion | √ | | |
| | 7.2 types of motion | 7.2 Definition of force and gravitational force | | √ | |
| | 7.3 motion in a straight line | 7.3 effects of Force | | | √ |
| | 7.4 Forces | 7.4 Measuring forces | | √ | |
| | 7.5 Force and motion | 7.5 Definition of Energy | | √ | |
| | 7.6 Energy (Forms and Conversion of Energy, source of energy, Conservation of energy) | 7.6 Energy (Conversion of Energy, energy source, conservation of energy) | √ | | |
| total | 52 | 52 | 46 | 4 | 2 |

As shown in Table 8, most contents and sub-contents stated in the syllabus were encompassed in the textbook. There are about fifty-two main and sub-contents stated in the syllabus and the textbook. Among these, 46(88.46%) contents are aligned and 4(7.69%) were partially aligned and 2(3.84%) were not aligned between the syllabus and the textbook.

Analyzing the Alignments of Cognitive Levels Development

In this section, efforts were made to analyze the alignments of the levels of cognitive development between the syllabus and the textbook prepared by the Amhara National Regional state education Bureau.

Table 9: Level of Cognitive Development in the Textbook (Table A)

| Level of cognitive development/Bloom's Taxonomy | | | | | | | |
|---|----------|------------|-------|---------|----------|--------|----------|
| Chapter | Remember | Understand | Apply | Analyze | Evaluate | Create | subtotal |
| 1 | 2 | 7 | 3 | 0 | 0 | 0 | 12 |
| 2 | 3 | 1 | 2 | 1 | 0 | 0 | 7 |
| 3 | 1 | 4 | 1 | 0 | 0 | 0 | 6 |
| 4 | 6 | 6 | 2 | 2 | 0 | 2 | 18 |
| 5 | 3 | 8 | 2 | 0 | 0 | 0 | 13 |
| 6 | 2 | 5 | 2 | 1 | 0 | 0 | 10 |
| 7 | 2 | 5 | 1 | 2 | 0 | 0 | 10 |
| Subtotal | 19 | 36 | 13 | 6 | 0 | 2 | 76 |

Table 9 indicates terms that are used to indicate the cognitive development levels expected from the students' learning outcomes in the textbook. Among the 76 terms 68 (89.47%) indicate the lower-level thinking skills (remember, understand and apply levels).

Table 10: Level of Cognitive Development in the Syllabus (Table B)

| Level of cognitive development/Bloom's Taxonomy | | | | | | | |
|---|----------|------------|-------|---------|----------|--------|----------|
| Chapter | Remember | Understand | Apply | Analyze | Evaluate | Create | Subtotal |
| 1 | 4 | 3 | 3 | 0 | 0 | 0 | 10 |
| 2 | 0 | 1 | 4 | 1 | 0 | 0 | 6 |
| 3 | 1 | 4 | 1 | 0 | 0 | 0 | 6 |
| 4 | 4 | 8 | 1 | 2 | 0 | 0 | 15 |
| 5 | 3 | 5 | 0 | 1 | 0 | 0 | 9 |
| 6 | 4 | 7 | 2 | 0 | 0 | 0 | 13 |
| 7 | 6 | 5 | 5 | 0 | 0 | 0 | 16 |
| Subtotal | 22 | 33 | 16 | 4 | 0 | 0 | 75 |

As shown in Table 10, most of the terms indicated that the cognitive development levels expected from the students' learning outcomes in the syllabus are the lower-level thinking skills, among the 75 terms 71(96.67%) are concentrated at remember, understand and apply levels.

Table 11: Ratio Table for Table 9

(table a_i)

| Level of cognitive development/Bloom's Taxonomy | | | | | | | |
|---|----------|------------|--------|---------|----------|--------|----------|
| Chapter | Remember | Understand | Apply | Analyze | Evaluate | Create | Subtotal |
| 1 | 0.0263 | 0.0921 | 0.0395 | 0 | 0 | 0 | 0.1579 |
| 2 | 0.0395 | 0.0132 | 0.0263 | 0.0132 | 0 | 0 | 0.0921 |
| 3 | 0.0132 | 0.0526 | 0.0132 | 0 | 0 | 0 | 0.0789 |
| 4 | 0.0789 | 0.0789 | 0.0263 | 0.0263 | 0 | 0.0263 | 0.2368 |
| 5 | 0.0395 | 0.1053 | 0.0263 | 0 | 0 | 0 | 0.1711 |
| 6 | 0.0263 | 0.0658 | 0.0263 | 0.0132 | 0 | 0 | 0.1316 |
| 7 | 0.0263 | 0.0658 | 0.0132 | 0.0263 | 0 | 0 | 0.1316 |
| Subtotal | 0.25 | 0.4737 | 0.1711 | 0.0789 | 0 | 0.0263 | 1 |

Table 11 is a ratio table constructed from Table 9 by dividing each cell to total number of terms in the textbook that indicate cognitive level development (which is 76).

Table 11: Ratio Table for Table 10(table b_i)

| Level of cognitive development/Bloom's Taxonomy | | | | | | | |
|---|----------|------------|--------|---------|----------|--------|----------|
| Chapter | Remember | Understand | Apply | Analyze | Evaluate | Create | Subtotal |
| 1 | 0.0533 | 0.04 | 0.04 | 0 | 0 | 0 | 0.1333 |
| 2 | 0 | 0.0133 | 0.0533 | 0.0133 | 0 | 0 | 0.08 |
| 3 | 0.0133 | 0.0533 | 0.0133 | 0 | 0 | 0 | 0.08 |
| 4 | 0.0533 | 0.1067 | 0.0133 | 0.0267 | 0 | 0 | 0.2 |
| 5 | 0.04 | 0.0667 | 0 | 0.0133 | 0 | 0 | 0.12 |
| 6 | 0.0533 | 0.0933 | 0.0267 | 0 | 0 | 0 | 0.1733 |
| 7 | 0.08 | 0.0667 | 0.0667 | 0 | 0 | 0 | 0.2133 |
| Subtotal | 0.2933 | 0.44 | 0.2133 | 0.0533 | 0 | 0 | 1 |

Table 12 is a ratio table constructed from Table 10 by dividing each cell to total number of terms in the syllabus that indicate cognitive level development (which is 75).

Table 12: Absolute Value Discrepancy Table /table a_i - table b_i /

| Chapter | Level of cognitive development/Bloom's Taxonomy | | | | | |
|----------------------------|---|------------|--------|---------|----------|--------|
| | Remember | Understand | Apply | Analyze | Evaluate | Create |
| 1 | 0.027 | 0.0521 | 0.0005 | 0 | 0 | 0 |
| 2 | 0.0395 | 0.0002 | 0.027 | 0.0002 | 0 | 0 |
| 3 | 0.0002 | 0.0007 | 0.0002 | 0 | 0 | 0 |
| 4 | 0.0256 | 0.0277 | 0.013 | 0.0004 | 0 | 0.0263 |
| 5 | 0.0005 | 0.0386 | 0.0263 | 0.0133 | 0 | 0 |
| 6 | 0.027 | 0.0275 | 0.0004 | 0.0132 | 0 | 0 |
| 7 | 0.0537 | 0.0009 | 0.0535 | 0.0263 | 0 | 0 |
| Sum(Σ) | 0.0433 | 0.0337 | 0.0423 | 0.0256 | 0 | 0.0263 |
| Overall alignment index(p) | 0.914 | | | | | |

The values of the discrepancy table (Table 13) was formulated using Table 9 up to Table 12 to calculate the overall alignment index for the levels of cognitive development using Porter's formula (2002) in four steps. The first step was creating two parallel tables of frequencies for the textbook and the syllabus. The second step was computing the ratio, Table 11 and Table 12(table a_i and table b_i) by dividing the value of each cell by the total number of cells (n) in the respective table. The third step is calculating the absolute value discrepancy between each cell in the ratio tables of the corresponding tables. The fourth step is computing the alignment index using Porter's formula (2002) as shown below.

$$P = 1 - \sum_{i=1}^n \frac{|a_i - b_i|}{2}$$

Where **p** is the alignment index, **n** is the sum of the number of cells in the table and **a_i** and **b_i** are values at the **ith** cell in the ratio table **a** and **b**. The value of the calculated alignment index (P=0.914) showed that the level of cognitive development stated in the national syllabus has an acceptable alignment with the cognitive level of development described in the textbook. The value of the alignment index runs from **0 to 1** and the larger the alignment index the strength of the alignment between the comparable materials.

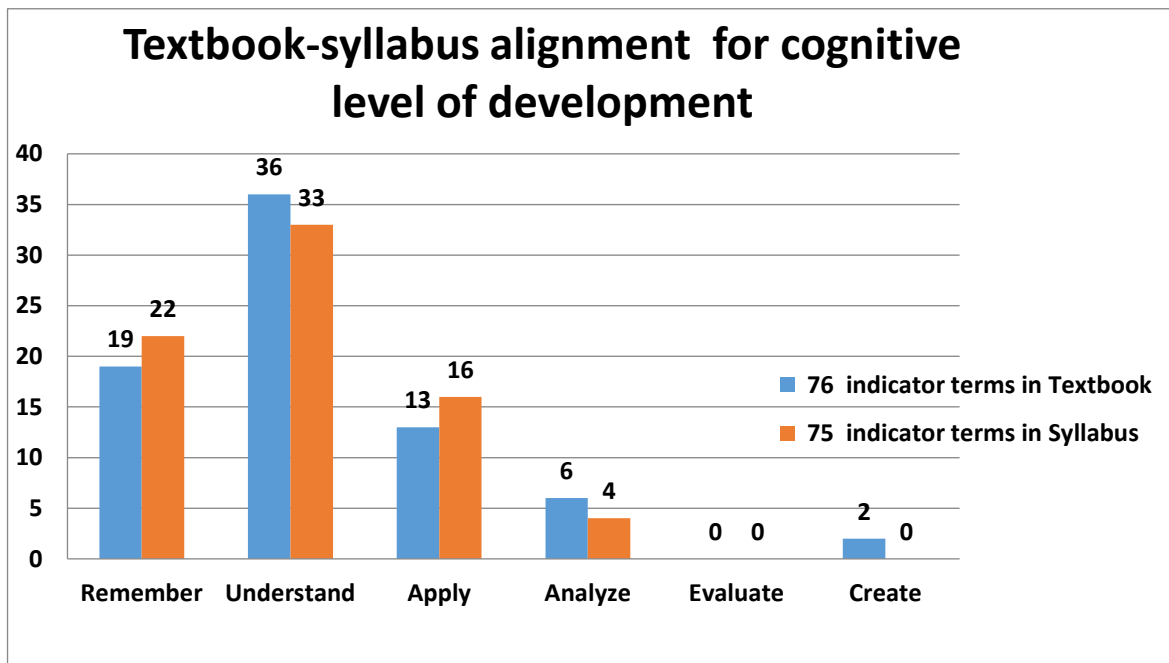


Figure 2: Bar graph for textbook-syllabus overall alignments of cognitive level development

As indicated in Figure 2, the cognitive levels of development stated in the syllabus are acceptably aligned with those described in the textbook.

DISCUSSION AND INTERPRETATION

The newly prepared general science textbook encompasses seven chapters on which the first chapter is deals about basic concepts of science, the next two chapters deal about chemistry contents, the 4th and 5th chapters deal about biology contents, and the 6th and 7th chapters deal about physics contents. The focus of this study was on examining the alignments of this textbook with the national syllabus.

Regarding the first research question, concerning the alignments of SLOs between the textbook and the syllabus. As it was indicated in Tables 1 to 7, there are 76 SLOs stated in the national syllabus and 78 SLOs in the textbook. Among these SLOs, 61(79.22%) of them were aligned, 3(3.90%) were partially aligned, and 13 (16.88%) were not aligned. From this, it is possible to conclude that the SLOs described in the textbook were not perfectly aligned with the SLOs stated in the national curriculum. As with this alignment, it is possible to say that the textbook was prepared to satisfy the national aims and goals, but it lacks perfect alignment. Since the textbook should be an embodiment of the syllabus. Scholars researched that textbook-syllabus alignment enhanced the

students' attainment by reducing the gap between the curriculum developer and the implementer (Hume & Coll, 2010). According to Bhatti, Jumani [9], a lack of proper alignment between textbook and syllabus will lead the teachers' instruction into other objectives other than the suggested objectives in the syllabus and reflects a lack of coordination between syllabus developers and textbook writers. This thought of scholars indicated the need for perfect alignment between the textbook and the syllabus.

Regarding the second research question, contents and sub-contents were analyzed and the finding indicated that 88.46% of the contents were aligned, 7.69% were partially aligned, and 3.85% were not aligned between the textbook and the national syllabus. As scholars indicated the contents of the textbook should refer to the contents of the syllabus[3, 11]. From this result, it is possible to disclose that, in terms of content alignment the textbook was prepared in a good alignment with the syllabus even if it lacks perfect alignment.

Regarding the third research, the finding indicated that the overall alignment index (p) was 0.914. This value indicated the existence of good alignment for the cognitive development levels between the textbook and the syllabus. As scholars indicated that content alignment indicated the quality of the textbook [3, 16].

Regarding the fourth research question, Figure 2 indicated that most of the cognitive development levels listed were the lower level thinking both in the textbook and the syllabus. In the textbook there are 76 cognitive level development terms, among them, 68(89.47%) are lower-level

indicator terms and only 8(10.53%) are higher order thinking level indicator terms. As different scholars indicated that the 21st-century learning needs to develop the higher-order thinking ability of students. In this respect, both the textbook and the syllabus were designed to satisfy only lower-level thinking. But the roadmap developed by MoE indicated one of the reasons that the need of changing the curriculum was integrating higher-order thinking in the curriculum materials which was not included in the previous curriculum materials [14]. But the general science grade seven curriculum documents did not scaffold higher order thinking skills.

SUMMARY, CONCLUSION AND RECOMMENDATION

Summary

The purpose of this study was to check the alignment of the grade seven general sciences textbook with the national syllabus in terms of content, students learning outcomes, and level of cognitive development as well as to examine the extent of the curriculum documents entertain higher-order thinking skills. In Ethiopia, different attempts were made to have a quality textbook that aligned perfectly with the national syllabus but the x-textbooks, in general, were blamed for content overload and misalignment with the national goals and aims as well as unable to promote higher order thinking skills. The government attempted to minimize this problem by performing curriculum changes, the 2021 curriculum change was one of them [14]. This research was focused

on examining the alignments between the newly prepared grade seven textbook and the 2021 syllabus using the following research questions

- How much the SLOs stated in the national syllabus aligned with at the start of each chapter aligned with the described SLOs in the newly prepared grade seven general sciences textbook?
- What are the contents and sub-contents' degrees of alignment between the syllabus and the textbook?
- Does the new Grade 7 General Science textbook cognitive level development align with the respected syllabus?
- To what extent cognitive development levels scaffold higher-order thinking?

These research questions were answered through quantitative research design and the finding of this study revealed that even though there was a lack of perfect alignment, most SLOs stated in the syllabus were aligned with the SLOs described in the students' textbooks. In the textbook there are 78 SLOs whereas in the syllabus there were 76 SLOs, among these 61 of them were perfectly aligned, 3 of them were partially aligned, and 13 of them were not aligned. Regarding the content alignments, among 52 contents 46 of them were aligned. Regarding the alignments of the cognitive development level, the overall alignment index was 0.914 which indicated that reasonably acceptable alignment between the textbook and the syllabus. But the stated levels of cognitive

development were mainly indicated as a lower level of thinking both in the national syllabus and in the textbook.

Conclusion

In view of the results and discussions, it was concluded that the students learning outcomes stated at the start of the newly prepared grade seven general science textbook was aligned in a reasonably acceptable manner but not perfectly aligned with the syllabus. But the cognitive level development described in the national syllabus does not contain all the necessary levels of cognitive development. It indicates only the lower level of cognitive development in the Bloom Taxonomy.

Recommendation

The newly prepared grade seven general science textbook was prepared as per the national syllabus which revealed reasonable alignment but lacks perfect alignment. In addition, both the syllabus and the textbook did not address all the levels of cognitive development, in Bloom's Taxonomy. Therefore, there is a need of reconsidering these levels of cognitive development to satisfy the need for 21st-century learning issues. When a new curriculum is put together or when a major revision is done at any level, several learning trajectories need to be incorporated into the curriculum. It is essential to discuss the learning trajectory that leads to the expected outcomes. So,

this research highly recommended to Ethiopian MoE reconsiders the syllabus in terms of the level of cognitive development and perfect alignment cases to enhance the quality of the textbook.

Limitations of the study

The limitation of this study was that it was unable to assess the alignments of designed activities, teaching methods, and evaluation strategies between the textbook and the national syllabus.

Future research

There are many cases for future study concerning to the alignment issues of general science textbook for grade seven. To list two of them,

- Studying the textbook-syllabus alignment in terms of the designed teaching strategies, designed activities, and designed assessment techniques.
- Conducting comparative study concerning of the overall aspects of the general science textbooks within different regions.

ACKNOWLEDGMENT

Firstly, I would like to thank the almighty God and move to Professor Solomon Melesse, to create the opportunity to conduct this content alignment analysis research and provide valuable comments and advice. My thanks are also great to Ehetgebriel Aregahagn (PhD Candidate) for her kindness to provide all the new national curriculum materials.

REFERENCES

1. Bhardwaj, A., *Importance of education in human life: A holistic approach*. International Journal of Science and Consciousness, 2016. 2(2): p. 23-28.

2. SAEED, M. and S. RASHID, *Alignment between chemistry curriculum and textbooks at secondary level*. The Sindh University Journal of Education-SUJE, 2014. **43**.
3. Panezai, K. and A.Q. Kakar, *Alignment of National Curriculum with Textbooks of Mathematics for Grade V and General Science of Grade VIII in Baluchistan*. Journal of Education & Humanities Research, University of Balochistan, Quetta-Pakistan, 2019. **8**(II).
4. Dalim, S.F. and M.M.M. Yusof. *Quantitative method of textbook evaluation for chemistry (KBSM) Form 4 textbook*. in *Proceeding of the International Conference on Social Science Research, ICSSR*. 2013. Citeseer.
5. Allington, R.L., *You cant learn much from books you cant read*. Educational leadership, 2002. **60**(3).
6. Shahmohammadi, N., *Content analysis of elementary science text books based on the achievment motivation constructs*. Procedia-Social and Behavioral Sciences, 2013. **84**: p. 426-430.
7. McFadden, L., *District learning tied to student learning*. Phi Delta Kappan, 2009. **90**(8): p. 544-553.
8. Fan, L. *Principles and processes for publishing textbooks and alignment with standards: A case in Singapore*. in *APEC Conference on Replicating Exemplary Practices in Mathematics Education, Koh Samui, Thailand*. 2010.
9. Bhatti, A.J., N.B. Jumani, and M. Bilal, *Analysis of Alignment between Curriculum and Biology Textbook at Secondary Level in Punjab*. Pakistan Journal of Social Sciences (PJSS), 2015. **35**(1).
10. Fonthal, G., *Alignment of state assessments and higher education expectations: Definition and utilization of an alignment index*. 2004: University of California, Irvine.
11. Rahmawati, L., *A content analysis of the English textbook" Primary English as a Second Language"*. 2018, UIN Sunan Ampel Surabaya.
12. Squires, D., *Curriculum alignment research suggests that alignment can improve student achievement*. The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 2012. **85**(4): p. 129-135.
13. Krippendorff, K., *The content analysis reader*. 2009: Sage.
14. Teferra, T., et al., *Ethiopian education development roadmap (2018-30)*. An integrated Executive Summary. Ministry of Education Strategy Center (ESC) Draft for Discussion: Addis ababa, 2018.
15. Porter, A.C., *Measuring the content of instruction: Uses in research and practice*. Educational researcher, 2002. **31**(7): p. 3-14.
16. Fulmer, G.W., *Estimating critical values for strength of alignment among curriculum, assessments, and instruction*. Journal of Educational and Behavioral Statistics, 2011. **36**(3): p. 381-402.

PHYTOCHEMISTRY OF SELECTED GAMBIAN TRADITIONAL MEDICINAL PLANTS

Alhagie Drammeh¹, Momodou K.A Sowe¹, Anthony Adjivon¹, Momodou Salieu Sowe^{1*}

¹Chemistry Unit, Division of Physical & Natural Sciences, School of Arts & Sciences, University of The Gambia, Brikama Campus, The Gambia.

*Corresponding Author Email: mssowe@utg.edu.gm

ABSTRACT

Traditional medicine has played a crucial role in the treatment and management of different human diseases since centuries ago in many African communities and traditions. Plants are a potent source of food and medicine in African communities. Malaria, diabetes, and parasitic diseases are common in Africa and cases can reach alarming levels occasionally. In this research, we studied the phytochemical constituents of popular plants in traditional medicine in The Gambia. The leaves of *Cassia tora* (Fabaceae), *Azadirachta indica* (Meliaceae) and *Vernonia amygdalina* (Asteraceae), the bark of *Khaya senegalensis* (Meliaceae), and roots of *Cassia sieberiana* (Fabaceae) respectively, were extracted by maceration in ethanol (90%). The samples (crude ethanol extract, n-hexane, and DCM fractions) were screened for phytochemical profile. The ethanol extract, n-hexane, and DCM fractions revealed Alkaloids, Saponins, Tannins, Phenol, Steroids, Flavonoids, Terpenoids, and Quinones. These phytochemicals are suggested to contribute to the efficacy of the plants in traditional medicinal application in The Gambia. It is hoped that the findings in this research will contribute to chemistry education through research on African medicinal plants and their healing properties. [African Journal of Chemical Education—AJCE 13(1), January 2023]

INTRODUCTION

Traditional medicine has existed since time immemorial to manage or treat various human ailments [1][2]. More than 60% of the world's population depends on plants for traditional or local treatment of infectious and inflammatory diseases [3]. Similarly, reports have indicated that traditional medicine is the first line of medication in many parts of Africa thus about 80% of the population sought traditional complementary medicine [4][5][6]. Disease prevalence is still a major problem in tropical and sub-tropical countries most especially malaria despite significant strides made in the past in malarial treatment and prevention[7][8][9]. Malaria is caused by infected mosquito bites which spread parasites through the human blood [10].

The Gambia is located in sub-Saharan Africa and the country is characterized by warm climatic conditions in several months of the year and a rainy season mostly from June to September annually [11]. The country is covered in part by forests with a variety of plant and animal species. An estimated 150 different plant species from a variety of plant families can be found in The Gambia [12]. As a result, plants are an important recipe in traditional medicine to treat diseases such as malaria, diarrhea, cough, and skin infections.

The West African Health Organization (WAHO) has identified *Ageratum conyzoides* L. (Asteraceae), *Cymbopogon citratus* (DC.) (Poaceae), *Sarcocephalus latifolius* (Rubiaceae), *Securidaca longepedunculata* Fres. (Polygalaceae), *Senna occidentalis* (L.) Link (Fabaceae) and *Senna podocarpa* (Fabaceae) as medicinal plants found in The Gambia and have been used in

traditional medicine to manage ailments [13]. The pharmacological properties and phytochemical constituents of these plants have been documented by WAHO. However, there are other plants used by traditional herbal medicinal practitioners in The Gambia and their secondary metabolite composition, chemical profile, and pharmacological effects are yet to be determined. *Cassia sieberiana* (Fabaceae), *Azadirachta indica* (Meliaceae), *Vernonia amygdalina* (Asteraceae), *Khaya senegalensis* (Meliaceae), and *Cassia tora* (Fabaceae) are plants used in The Gambia for traditional and or local medicinal purposes [13].

Cassia sieberiana is known as West African laburnum and locally called "Sindian". It is a tropical deciduous woody shrub belonging to the Fabaceae family widely distributed in many parts of Africa [14]. The plant has significant therapeutic value. The root and stem bark formulation are effective against dysmenorrhea and gastric ulcer pain, leave infusion for stomach ache, ulcer, and diarrhea, and root powder for malarial treatment [15]. *Azadirachta indica* "Neem" is an evergreen tree of family Meliaceae cultivated in various parts of The Gambia. The leaves, fruits, flowers, and bark are attributed to anticancer, antihypertension, antidiabetic, antimalarial, and treatment of cardiac diseases [16]. *Vernonia amygdalina* "bitter leaf" is known for its bitter taste. Leaves of *V. amygdalina* are formulated and used in folkloric malarial treatment, cough, and dysentery. *Vernonia amygdalina* is a fast-growing plant with shrubs that extends to 2-3 m in height and leave growth is up to 20 cm [17]. *Khaya senegalensis* also called African mahogany, is a popular medicinal plant among the people of The Gambia. The stem bark is used in the treatment of malaria, headache, and

cough. Cassia tora on the other hand called “Jambanduro” is being used for food and medicinal purposes. Leave concoctions are an antidote for poison, normalizes cholesterol levels, and relieves hemorrhoids. The leaves are nerve tonic and a source of edible leafy food.

In this study, *Cassia sieberiana*, *Azadirachta indica* (Neem), *Vernonia amygdalina* (Bitter leaf), *Khaya senegalensis* (African mahogany), and *Cassia tora* plant parts were collected and extracted in ethanol by maceration. The extracts were fractionated in n-hexane and dichloromethane to isolate wide range of phytochemicals. The extracts and fractions were subjected to phytochemical screening. We report on the phytochemical profile of *C. sieberiana*, *A. indica*, *V. amygdalina*, *K. senegalensis* and *C. tora* and also suggest scientific bases for traditional medicinal uses of the plants in The Gambia.

EXPERIMENTAL

Materials

All chemicals and reagents used in this research are of analytical grade. They include ethanol, dichloromethane, n-hexane, methanol, and distilled water. The other chemicals used included chloroform, H₂SO₄, NaOH pellets, HCl, and anhydrous FeCl₃. Standard solutions such as dilute NaOH, 5% and 10% ferric chloride, and Wagner's reagent (Iodine in Potassium Iodide) were prepared and used as required.

A set of glassware such as a distillation apparatus, Erlenmeyer flasks, test tubes, and beakers were also used.

Plant collection and preparation

The plant species (Figure 1) were collected at different locations in The Gambia in the month of January 2021. The leaves of *Cassia tora*, *Azadirachta indica*, and *Vernonia amygdalina* were collected from The Gambia College's experimental farm at Brikama Campus, West Coast Region (16° 49' 30" W). The bark of *Khaya senegalensis* and roots of *Cassia sieberiana* were collected from the Nyambai Forest in Brikama, West Coast Region (16° 49' 30" W). The collected plant parts were washed thoroughly with running water to remove sand and other particles attached. The leaves, root, and bark samples were air-dried under shade for three weeks. The dried samples were ground to fine powder using mortar and pestle. The powdered samples were placed in containers and stored at room temperature for extraction.

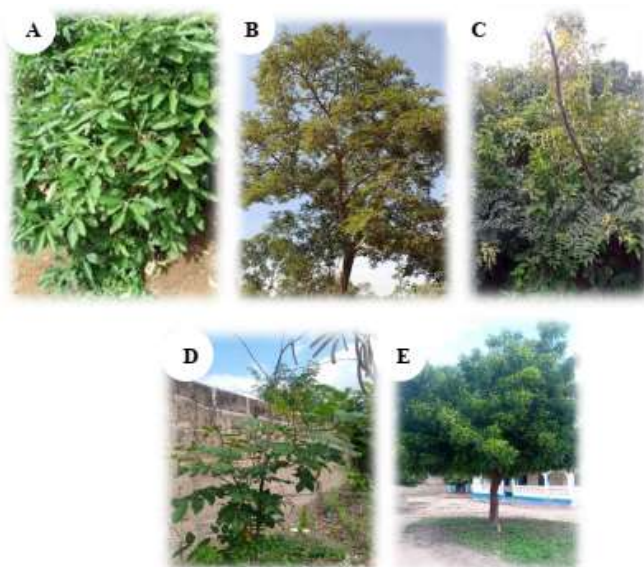


Figure 1. *Vernonia amygdalina* (A), *Khaya senegalensis* (B), *Cassia sieberiana* (C), *Cassia tora* (D), and *Azadirachta indica* (E) Plants.

Extraction procedure

The extraction procedure followed a maceration method by [18] with modification. A 10 g of powdered plant samples were placed in beakers containing 100 mL of 90% ethanol (1:10 g/mL). The beakers were sealed with aluminum foil and allowed to stand for two weeks at room temperature in the laboratory to allow phytochemical extraction. After two weeks, the mixture was filtered using Whatman No. 1 filter paper placed in a separatory funnel to separate the ethanol extract from the residue.

The ethanol (90%) extract was further fractionated in n-hexane and DCM (solvents of increasing polarity). Fractionation was done by mixing the ethanol extract with n-hexane and DCM

respectively in a separatory funnel. The mixture was vigorously shaken intermittently, and phase separation was allowed to take place. The ethanol extract, n-hexane, and DCM fractions were then collected and evaporated by steam distillation. After evaporation, the ethanol extract, n-hexane, and DCM fractions were labelled and kept at room temperature. The same procedure was done for each of the plant samples. A total of five (5) ethanol extracts, five (5) n-hexane, and five (5) DCM fractions were subjected to phytochemical screening.

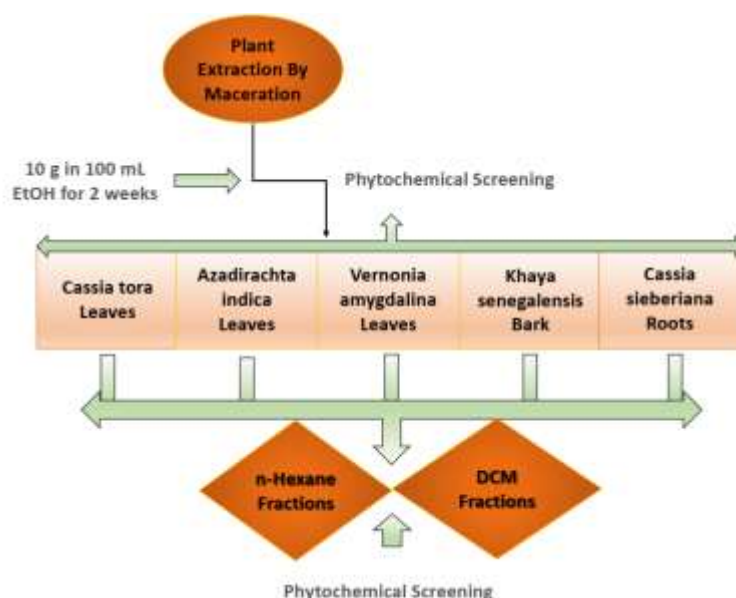


Figure 2. Plant Extraction Process

Phytochemical screening

The presence of eight (8) phytochemicals were determined in the ethanol leave extracts, n-hexane, and DCM fractions of *Cassia tora*, *Azadirachta indica* and *Vernonia amygdalina* and bark and root extracts and fractions of *Khaya senegalensis* and *Cassia sieberiana* respectively. The

phytochemical screening for Alkaloids, Saponins, Tannins, Phenol, Steroids, Flavonoids, Terpenoids and Quinones was conducted as stated below using methods previously reported by [19].

Tannin Test

The extract was added to 1 ml of the prepared 5% FeCl_3 in a test tube. The formation of greenish precipitate was indicative of Tannin presence in the extract.

Saponin Test

The extract was mixed with 20 mL distilled water in a graduated cylinder. The mixture was vigorously shaken for about 5 mins. Foam formation showed the presence of Saponins in the extract.

Phenol Test

2 mL of distilled water was added to the extract. Few drops of the prepared 10% FeCl_3 were then added to the mixture. The formation of blue or green colour showed the presence of phenols in the extract.

Steroid Test

Few drops of the extract were mixed with 10 mL CHCl_3 in a test tube. 10 mL of concentrated H_2SO_4 was added dropwise to the side of the test tube. The formation of a red upper layer and a yellowish lower layer showed the presence of steroids in the extract.

Flavonoid Test

Few drops of dilute NaOH were added to the extract to form a yellow solution. The solution turned colourless with the gradual addition of dilute H₂SO₄. This showed Flavonoids were present in the extract.

Terpenoid Test

The extract was mixed with 2 mL of chloroform. The solution was then mixed with 3 mL of concentrated H₂SO₄ to form a ring layer. The formation of a red-brown precipitate shown Terpenoids was present.

Quinone Test

The extract was added to 1 mL of concentrated H₂SO₄ and the formation of a reddish colour showed Quinone presence in the extract.

Alkaloid Test

Extract with few drops of the Wagner's reagent (Iodine in Potassium Iodide). The formation of a reddish-brown precipitate showed Alkaloids were present.

RESULT AND DISCUSSION

Phytochemical screening of the ethanol, n-hexane, and dichloromethane root extracts of *Cassia sieberiana* (Table 1) revealed the presence of Saponins (**1**) in all solvent extracts. However, Steroids (**2**) were detected only in the DCM extract while Terpenoids (**3**) were detected in the ethanol

and DCM extracts. Tannins (6) and Phenols (7) were also detected in the ethanol and DCM extracts respectively. In contrast to a report by Macedo et al.[20] in which Flavonoids were detected in hydroethanolic (1:1) leave extract of *Cassia sieberiana*, we detect Flavonoids (5) in the n-hexane and DCM extracts alone. Therefore, ethanol/water solvent concentration might have influenced Flavonoid detection. Quinones (4) are also detected in the ethanol and DCM extracts. Alkaloids (8) are found in the ethanol extract only. It could be stated that Saponins, Quinones, Flavonoids, Alkaloids, and Terpenoids are present in *C. sieberiana*. Our results are in accordance with Ambadiang et al [21] and Manekeng et al. [22]. Ambadiang et al. isolated monobehenin, arachidic acid, *iso*-6-cassine, 3-O-methyl-chiro-inositol and sitosterol3-O-β-D-glucopyranoside from *C. sieberiana* and the plant extract showed significant antibacterial activity against *Escherichia coli*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* bacterial strains. This could be the reason for the efficacy of *C. sieberiana* in traditional medicine.

Table 1. Phytochemical Constituents of Root Extracts of *Cassia sieberiana*

| Phytochemicals | Ethanol Extract | n-Hexane Extract | DCM Extract |
|----------------|-----------------|------------------|-------------|
| Saponins | +++ | + | ++ |
| Steroids | - | - | +++ |
| Terpenoids | +++ | - | +++ |
| Quinones | +++ | - | +++ |
| Flavonoids | - | +++ | ++ |
| Tannins | +++ | - | + |
| Phenols | +++ | - | + |
| Alkaloids | ++ | - | - |

+++ = Highly detected, ++ = moderately detected, + = slightly detected, - = not detected

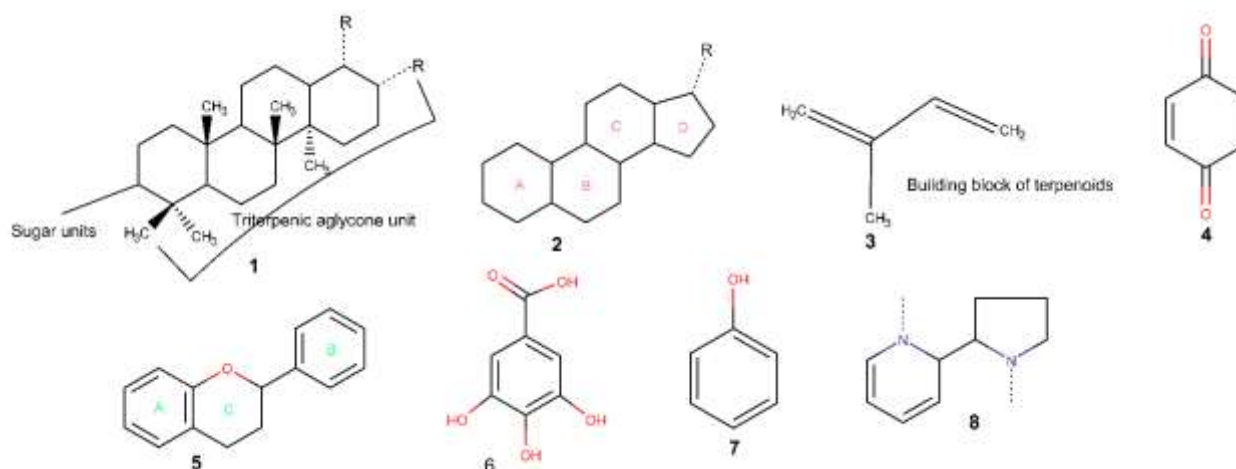


Figure 3. Structural Frameworks of Saponins (1), Steroids (2), Terpenoids (3), Quinones (4), Flavonoids (5), Tannins (6), Phenols (7), Alkaloids (8).

Table 2 shows the phytochemical constituents of bark extracts of *Khaya senegalensis*. Saponins, Steroids, Terpenoids, Quinones, Tannins, and Phenols are detected in the ethanol and n-hexane extracts while Flavonoids are absent. However, Flavonoids are found in the DCM extracts. *K. senegalensis* contains important phytochemicals. According to Dougnon et al.[23], the stem bark extract of *Khaya senegalensis* showed a strong minimum inhibitory concentration (25 mg/mL) against *Salmonella Typhimurium*, *Shigella spp.* and *Escherichia coli* disease-causing pathogenic strain growth. Kaur et al.[24] reported the antiplasmodial efficacy of *Khaya senegalensis* in which the ethanol bark extract showed moderate activity (IC_{50} 15-50 μ g/mL) against *P. falciparum*. This could explain the folkloric use of the plant in malarial treatment.

Table 2. Phytochemical Constituents of Root Extracts of *Khaya senegalensis*

| Phytochemical | Ethanol Extract | n-Hexane Extract | DCM Extract |
|---------------|-----------------|------------------|-------------|
| Saponins | +++ | ++ | +++ |
| Steroids | ++ | + | +++ |
| Terpenoids | +++ | +++ | + |
| Quinones | +++ | +++ | +++ |
| Flavonoids | - | - | + |
| Tannins | +++ | ++ | +++ |
| Phenols | +++ | ++ | +++ |
| Alkaloids | +++ | ++ | ++ |

+++ = Highly detected, ++ = moderately detected, + = slightly detected, - = not detected

Phytochemical screening of leaf extracts of *Cassia tora* shows Tannins, Phenols, Quinones, and Alkaloids in all solvent extracts (Table 3). Saponins are absent in the DCM extract and Flavonoids are not detected in the ethanol extract. In a report by Aryal et al.[25], antioxidant evaluation of the plant extract by radical scavenging using DPPH showed a potency of 9.898 µg/mL. Antioxidant activity study of methanol leaf extracts of *C. tora* by Chethana et al.[26] showed IC₅₀ between 86.48-215.62 µg/mL. The antioxidative property of the plant extracts might validate the therapeutic application of the plant in traditional medicine.

Table 3. Phytochemical Constituents of Leaves Extracts of *Cassia tora*

| Phytochemical | Ethanol Extract | n-Hexane Extract | DCM Extract |
|---------------|-----------------|------------------|-------------|
| Saponins | +++ | ++ | - |
| Steroids | +++ | ++ | ++ |
| Terpenoids | +++ | + | +++ |
| Quinones | +++ | +++ | ++ |
| Flavonoids | - | + | ++ |
| Tannins | +++ | +++ | +++ |
| Phenols | +++ | +++ | ++ |
| Alkaloids | ++ | + | +++ |

+++ = Highly detected, ++ = moderately detected, + = slightly detected, - = not detected

In table 4, Steroids, Terpenoids, Quinones, Tannins, Phenols, and Alkaloids are detected in all solvent extracts of *Azadirachta indica*. Flavonoids and Saponins are not detected in the ethanol and DCM extracts. However, the screened phytochemicals are observed to be present in *Azadirachta indica*. Cen-Pacheco et al.[27] revealed from the bark extracts of *Azadirachta indica* bioactive flavonoids 3-O-butyl(-)-epicatechin and O-butyl(-)-epigallocatechin. Another bioactive compound isolated from various plant parts of *Azadirachta indica* is Azadirachtin. This compound is attributed to antimalarial, anticancer, and antifeedant activity according to Fernandes et al.[28].

Table 4. Phytochemical Constituents of Leave Extracts of *Azadirachta indica*

| Phytochemical | Ethanol Extract | n-Hexane Extract | DCM Extract |
|---------------|-----------------|------------------|-------------|
| Saponins | ++ | + | - |
| Steroids | +++ | ++ | +++ |
| Terpenoids | +++ | + | ++ |
| Quinones | +++ | +++ | +++ |
| Flavonoids | - | +++ | ++ |
| Tannins | +++ | +++ | +++ |
| Phenols | +++ | ++ | + |
| Alkaloids | + | +++ | + |

+++ = Highly detected, ++ = moderately detected, + = slightly detected, - = not detected

Finally, it is observed that Saponins, Steroids, Terpenoids, Quinones, Tannins, and Alkaloids are present in the extracts of *Vernonia amygdalina* except for Flavonoids which are detected in the n-hexane and DCM extract (Table 5). The anti-inflammatory, antimalarial, antioxidant, and antitumor properties of the plant have been determined in other investigations [29]. Unsurprisingly, “bitter leave” is popular among herbalists in many parts of West Africa including The Gambia [30].

The findings of this research suggest that more research should be carried out by African universities to document the traditional uses vis-à-vis the chemical profiling and therapeutic benefits of traditional medicinal plants used in the The Gambia and other African countries. Therefore, there is need for more funding in Chemistry education in The Gambia for effective research and innovation in traditional medicine.

Table 5. Phytochemical Constituents of Leave Extracts of *Vernonia amygdalina*

| Phytochemical | Ethanol Extract | n-Hexane Extract | DCM Extract |
|---------------|-----------------|------------------|-------------|
| Saponins | +++ | ++ | + |
| Steroids | +++ | ++ | + |
| Terpenoids | +++ | ++ | ++ |
| Quinones | +++ | +++ | ++ |
| Flavonoids | - | ++ | + |
| Tannins | +++ | + | + |
| Phenols | +++ | ++ | +++ |
| Alkaloids | + | +++ | + |

+++ = Highly detected, ++ = moderately detected, + = slightly detected, - = not detected

CONCLUSION

The leaves of *Cassia tora*, *Azadirachta indica* and *Vernonia amygdalina*, the bark of *Khaya senegalensis* and roots of *Cassia sieberiana* were collected from The Gambia College's experimental farm and Brikama Nyambai Forest, West Coast Region. The plant parts were extracted in ethanol (90%) for two weeks and the crude extracts were fractionated in n-hexane and dichloromethane. The crude ethanol extract and solvent fractions were subjected to phytochemical screening. Our investigation revealed that Saponins, Steroids, Terpenoids, Quinones, Flavonoids, Tannins, Phenols,

Alkaloids are major phytoconstituents of *Cassia sieberiana*, *Azadirachta indica* (Neem), *Vernonia amygdalina* (Bitter leaf), *Khaya senegalensis* (African mahogany), and *Cassia tora*. Literature have shown significant antioxidant, anti-inflammatory, antimalarial, and antibacterial activity of the studied plant extracts. Therefore, the traditional medicinal efficacy of *Cassia sieberiana*, *Azadirachta indica* (Neem), *Vernonia amygdalina* (Bitter leaf), *Khaya senegalensis* (African mahogany), and *Cassia tora* could be attributed to the presence of the detected phytochemical constituents. Chemistry education and research in traditional medicine could offer an alternative approach to health care delivery in The Gambia and Africa in general.

ACKNOWLEDGMENTS

We thank the University of The Gambia for the laboratory facility and reagents. We also thank Mr. Sambou for the laboratory assistance.

REFERENCES

- [1] T. Lefebvre, E. Destandau, E. Lesellier, "Selective Extraction of Bioactive Compounds from Plants Using Recent Extraction Techniques: A review, *Journal of Chromatography A*, vol. 1635, pp.461770, Nov. **2021**, doi.org/10.1016/j.chroma.2020.461770.
- [2] E. Salmerón-Manzano, J. A. Garrido-Cardenas, and F. Manzano-Agugliaro, "Worldwide Research Trends on Medicinal Plants," *IJERPH*, vol. 17, no. 10, p. 3376, May **2020**, doi: 10.3390/ijerph17103376.
- [3] B. K. Wanjohi, V. Sudoi, E. W. Njenga, and W. K. Kipkore, "An Ethnobotanical Study of Traditional Knowledge and Uses of Medicinal Wild Plants among the Marakwet Community in Kenya," *Evidence-Based Complementary and Alternative Medicine*, vol. **2020**, pp. 1–8, Mar. 2020, doi: 10.1155/2020/3208634.
- [4] M. Makosa, S. Sithole, and S. Mukanganyama, "Evaluation of the Antimicrobial Effect of the Extracts of the Pods of *Piliostigma thonningii* (Schumach.) Milne-Redh.(Fabaceae)," *Advances*

- in *Pharmacological and Pharmaceutical Sciences*, vol. **2021**, pp. 1–12, Feb. 2021, doi: 10.1155/2021/6616133.
- [5] D. J. Newman and G. M. Cragg, “Natural Products as Sources of New Drugs over the Nearly Four Decades from 01/1981 to 09/2019,” *J. Nat. Prod.*, vol. 83, no. 3, pp. 770–803, Mar. **2020**, doi: 10.1021/acs.jnatprod.9b01285.
- [6] R. Rupani and A. Chavez, “Medicinal plants with traditional use: Ethnobotany in the Indian subcontinent,” *Clinics in Dermatology*, vol. 36, no. 3, pp. 306–309, May **2018**, doi: 10.1016/j.clindermatol.2018.03.005.
- [7] I. C. Ezenyi, V. Verma, S. Singh, S. E. Okhale, and B. Adzu, “Ethnopharmacology-aided antiplasmodial evaluation of six selected plants used for malaria treatment in Nigeria,” *Journal of Ethnopharmacology*, vol. 254, p. 112694, May **2020**, doi: 10.1016/j.jep.2020.112694.
- [8] N. P. Kadhila, M. Sekhoacha, M. Tselanyane, K. C. Chinsebu, and D. M. Molefe-Khamanga, “Determination of the antiplasmodial activity, cytotoxicity and active compound of *Pechuel-loeschea leubnitziae* O. Hoffm. (Asteraceae) of Namibia,” *SN Appl. Sci.*, vol. 2, no. 8, p. 1328, Aug. **2020**, doi: 10.1007/s42452-020-2926-6.
- [9] A. N. Bitombo *et al.*, “Antiplasmodial activities of indole alkaloids from *Tabernaemontana penduliflora* K. Schum (Apocynaceae),” *Fitoterapia*, vol. 153, p. 104941, Sep. **2021**, doi: 10.1016/j.fitote.2021.104941.
- [10] K. Okaiyeto, H. Hoppe, and A. I. Okoh, “Plant-Based Synthesis of Silver Nanoparticles Using Aqueous Leaf Extract of *Salvia officinalis*: Characterization and its Antiplasmodial Activity,” *J Clust Sci*, vol. 32, no. 1, pp. 101–109, Jan. **2021**, doi: 10.1007/s10876-020-01766-y.
- [11] The Gambia Demographic and Health Survey, 2013.
<https://dhsprogram.com/pubs/pdf/FR289/FR289.pdf>
- [12] L. Bojang, “NON-WOOD FOREST PRODUCTS IN THE GAMBIA,” p. 22.
<http://www.fao.org/3/X6691E/X6691E00.htm>
- [13] “west-african-herbal-pharmacopoeiaok.pdf.” <https://www.wahooas.org/web-ooas/sites/default/files/publications/2185/west-african-herbal-pharmacopoeiaok.pdf>
- [14] M.-A. Archer *et al.*, “Medicinal Uses of *Cassia Sieberiana*; A Review,” *International Journal of Sciences*, vol. 48, no. 2, p. 20, **2019**.
- [15] M.-A. Archer *et al.*, “Formulation and evaluation of capsules containing extracts of *Cassia sieberiana* for improved therapeutic outcome,” *Scientific African*, vol. 10, p. e00609, Nov. **2020**, doi: 10.1016/j.sciaf.2020.e00609.
- [16] J. F. Islas *et al.*, “An overview of Neem (*Azadirachta indica*) and its potential impact on health,” *Journal of Functional Foods*, vol. 74, p. 104171, Nov. **2020**, doi: 10.1016/j.jff.2020.104171.
- [17] O. R. Alara, N. H. Abdurahman, C. I. Ukaegbu, and N. A. Kabbashi, “Extraction and characterization of bioactive compounds in *Vernonia amygdalina* leaf ethanolic extract comparing

- Soxhlet and microwave-assisted extraction techniques,” *Journal of Taibah University for Science*, vol. 13, no. 1, pp. 414–422, Dec. **2019**, doi: 10.1080/16583655.2019.1582460.
- [18] M. Oroian, F. Dranca, and F. Ursachi, “Comparative evaluation of maceration, microwave and ultrasonic-assisted extraction of phenolic compounds from propolis,” *J Food Sci Technol*, vol. 57, no. 1, pp. 70–78, Jan. **2020**, doi: 10.1007/s13197-019-04031-x.
- [19] S. H. Ganatra, A. M. Ramteke, S. P. Durge, and S. U. Patil, “PHYTOCHEMICALS INVESTIGATION AND TLC PROFILING OF CYAMOPSIS TETRAGONOLOBA L. SEEDS (FABACEAE) - PEA FAMILY,” *International Journal of Pharmaceutical Sciences and Research*, vol. 4, p. 5.
- [20] T. Macedo *et al.*, “Cassia sieberiana DC. leaves modulate LPS-induced inflammatory response in THP-1 cells and inhibit eicosanoid-metabolizing enzymes,” *Journal of Ethnopharmacology*, vol. 269, p. 113746, Apr. **2021**, doi: 10.1016/j.jep.2020.113746.
- [21] M. M. M. Ambadiang *et al.*, “Bark extract of Cassia sieberiana DC. (Caesalpiniaceae) displayed good antibacterial activity against MDR gram-negative phenotypes in the presence of phenylalanine-arginine β -naphthylamide,” *BMC Complement Med Ther*, vol. 20, no. 1, p. 342, Dec. **2020**, doi: 10.1186/s12906-020-03148-3.
- [22] H. T. Manekeng *et al.*, “Anti-staphylococcal and antibiotic-potentiating activities of seven Cameroonian edible plants against resistant phenotypes,” p. 14, **2018**.
- [23] V. Dougnon *et al.*, “Assessment of the antibacterial effect of Khaya senegalensis on some Gram-negative bacteria,” *Bull Natl Res Cent*, vol. 45, no. 1, p. 107, Dec. **2021**, doi: 10.1186/s42269-021-00568-0.
- [24] H. Kaur, H. M. Mukhtar, A. Singh, and A. Mahajan, “Antiplasmodial Medicinal Plants: A Literature Review on Efficacy, Selectivity and Phytochemistry of Crude Plant Extracts,” *Journal of Biologically Active Products from Nature*, vol. 8, no. 5, pp. 272–294, Sep. **2018**, doi: 10.1080/22311866.2018.1526651.
- [25] S. Aryal, M. K. Baniya, K. Danekhu, P. Kunwar, R. Gurung, and N. Koirala, “Total Phenolic Content, Flavonoid Content and Antioxidant Potential of Wild Vegetables from Western Nepal,” *Plants*, vol. 8, no. 4, p. 96, Apr. **2019**, doi: 10.3390/plants8040096.
- [26] K. R. Chethana, F. S. Senol, I. E. Orhan, K. R. Anilakumar, and R. S. Keri, “Cassia tora Linn.: A boon to Alzheimer’s disease for its anti-amyloidogenic and cholinergic activities,” *Phytomedicine*, vol. 33, pp. 43–52, Sep. **2017**, doi: 10.1016/j.phymed.2017.06.002.
- [27] F. Cen-Pacheco *et al.*, “Studies on the bioactive flavonoids isolated from *Azadirachta indica*,” *Natural Product Research*, vol. 34, no. 24, pp. 3483–3491, Dec. **2020**, doi: 10.1080/14786419.2019.1579808.
- [28] S. R. Fernandes *et al.*, “Chemistry, bioactivities, extraction and analysis of azadirachtin: State-of-the-art,” *Fitoterapia*, vol. 134, pp. 141–150, Apr. **2019**, doi: 10.1016/j.fitote.2019.02.006.

- [29] J. Wang *et al.*, “Steroidal Saponins from *Vernonia amygdalina* Del. and Their Biological Activity,” *Molecules*, vol. 23, no. 3, p. 579, Mar. **2018**, doi: 10.3390/molecules23030579.
- [30] I. T. Oyeyemi, A. A. Akinlabi, A. Adewumi, A. O. Aleshinloye, and O. T. Oyeyemi, “*Vernonia amygdalina* : A folkloric herb with anthelmintic properties,” *Beni-Suef University Journal of Basic and Applied Sciences*, vol. 7, no. 1, pp. 43–49, Mar. **2018**, doi: 10.1016/j.bjbas.2017.07.007.

QUALITATIVE MOLECULAR ORBITAL THEORY SUITED FOR THE HIGH SCHOOL STUDENT

Rasmus Persson

Department of Pedagogical, Curricular and Professional Studies, University of Gothenburg,
Sweden

E-mail: rasmusp@chem.gu.se

ABSTRACT

We introduce and discuss a pedagogical approach to molecular orbital theory which, devoid of any mathematics beyond simple arithmetic on experimental data, is suitable as an introduction to chemical bonding concepts as a complement to Lewis theory in high-school chemistry. Examples are discussed that highlight the reasoning that could be imparted to students. This exercise may also give rise to discussions about scientific theories and “truth.” Notably, within the realm of our qualitative theory, we conclude that HF is a double-bonded diatomic. [*African Journal of Chemical Education—AJCE 13(1), January 2023*]

INTRODUCTION

In a recent article in this Journal, Barke and Harsch [1] discuss the chemical bond within the purview of nineteenth century valence theory. Their discussion prompted the present contribution, in which we aim to approach the chemical bond using twenty-first century quantum theory, but at a level suitable for the upper-level secondary school student.

We must start this paper by recognizing that there is no rigorous definition of the chemical bond; definitions for it hitherto advanced are all arbitrary to some extent. In practice, atoms are considered chemically bonded if found that the aggregate that they form is sufficiently stable to allow isolation and characterization. Despite this inherent arbitrariness which would seem to preclude *prima facie* rigorous discussion of the topic, it is a very common topic in the chemical education literature. The issue in these discussions center around what is the “right reason” for chemical bonds to form, focusing on the significance of different partial energy contributions and other terms in quantum mechanics [2-10]. Needless to say, such discussions are not likely to influence classroom teaching, whatever their conclusion.

From a pedagogical point of view, there is no point in teaching theories that are more complicated than required to explain and organize whatever chemical knowledge the student needs for future studies or work. Lewis theory [11], for instance, correctly predicts the molecular formula of water as H₂O (and, with its VSEPR extension [12,13], also the bent geometry of this molecule) from solely the information contained in a minimalistic periodic table, that is, the number of valence

electrons of each element. Although true that the concept of the “valence electron” needed for this prediction is not easily defined without recourse to quantum theory or experimental ionization energies, the actual number of electrons that are considered “valence” can nevertheless be inferred from the periodic table and conceptualized using, for instance, Bohr’s atomic model. This means that Lewis theory is conceptually self-contained without quantum mechanics.

Indeed, in high-school chemistry, the chemical bond is typically approached within the framework of Lewis theory (the concept of atomic orbitals introduced before that provides the necessary definition of the “valence electron”). In the introductory chemistry courses at the university level, Lewis theory still predominates, but quantum theory is usually covered as well. At this point, many textbooks purport, at least indirectly, to provide an “explanation” for Lewis theory from quantum theory, but this inevitable requires some “hand-waving.” As a case in point, we have valence-bond theory which, in the form introduced in introductory university level chemistry courses, basically amounts to nothing more than Lewis theory with the electron dot structures replaced with computer-generated imagery of hybrid orbitals. In other words, when Lewis theory predicts, for instance, carbon to be tetravalent, the textbook will state that the carbon is “sp³-hybridized”; but short of appealing to Lewis theory itself, there is no simple argument to reach this conclusion independently.

At the high-school level, the theoretical treatment of the chemical bond is arguably what separates chemistry as a discipline most clearly from physics. Indeed, whereas in high-school

physics courses, students are taught that electrons repel each other vigorously on account of their identical electrical charge; in their chemistry courses, they are instead taught that electrons “pair up”.

It is hard to imagine a more perfect obstacle to knowledge transfer between these two subjects when they teach incompatible properties of the electron! When the inquiring student asks about this apparent contradiction, the high-school instructor often has no choice but to say that it is explained by quantum mechanics in university level courses and cannot provide any examples of quantum-mechanical reasoning at a level that the high-school student would grasp. While the core high-school curriculum usually includes some notions of quantum mechanics, typically atomic orbitals and the shell structure of atoms [14], this is insufficient for answering the student’s question directly and serves little purpose in high-school chemistry beyond providing a definition of “valence electrons”.

The topic of this paper is to introduce a qualitative, theoretical framework for the chemical bond that is suitable for the inquisitive high-school student and still devoid of Lewis theory. This qualitative molecular orbital theory is intended to serve as a starting point for future studies at the university level, while avoiding entrenching the student with the misconceptions [15] observed by Autschbach [16]. The prerequisite knowledge of the student is at least a superficial understanding of atomic orbitals and the corresponding Aufbau-principle covered in most high-school chemistry textbooks; the reader of this paper (in his or her capacity as the instructor) is expected to have a more complete understanding of quantum mechanics from university-level chemistry courses in order to easily follow along with the arguments in this paper and to present them (or similar ideas) to the

student without undue distortion. This last point is important, as distorted views (likely detrimental to the progress of learning) of what orbitals are have been identified even for students in college courses on the topic [15].

Before we proceed, it is useful to highlight in which way our approach is novel. Qualitative discussions around molecular orbital diagrams can be found in most introductory chemistry courses at the university level. However, these invariably start out from precalculated molecular orbital diagrams. The discussion thus cannot proceed from the same basic input that Lewis theory of bonding does, viz. basic atomic structure apparent from the periodic table. This hampers the student's own inquisitive mind and thinking, as the discussion has to be scaffolded on obscure (at that point in time to the student, anyway) computer calculations.

QUALITATIVE MOLECULAR ORBITAL THEORY

All the student needs to know at this point is that an “orbital” is a mathematical function describing the motion of an electron without pinpointing its position at any given time, but rather gives (after taking the square of the modulus) the probability distribution associated with this motion. Most importantly, connected with the electron's motion is an invariant energy (which is the sum of kinetic and potential energy contributions) and so each orbital is said to have a certain energy. The energy of the atomic nuclei, in particular, their mutual electrostatic repulsion is not included.

The qualitative treatment that we shall present is based on the following principles:

1. Combining two valence atomic orbitals on different atomic centers yields two molecular orbitals, of which one lies higher (called “antibonding”) and the other lies lower (called “bonding”) in energy than the energy of the atomic ones. This can be understood as the motion described by the electron in the molecule being a superposition of its motion in the isolated atom [17].
2. The increase or decrease in energy of said molecular orbitals with respect to their atomic counterparts is the more pronounced the more similar in energy these latter are, and the more the orbitals overlap, that is, the more similar the spatial motions they describe are with respect to a common molecule-frame coordinate system.
3. As a corollary to the above point due to reasons of symmetry, in diatomics, the atomic orbitals are restricted in with which atomic orbitals they may combine, so that s- orbitals may combine with other s- and pz-orbitals, and p-orbitals may combine with other p-orbitals of the same type, but other types of mixing are not possible.
4. Electrons are distributed among the molecular orbitals from low to high energy in accordance with the Aufbau-principle of two electrons per orbital.

These principles can be shown mathematically in a more complete treatment (see e. g., Ref. 18). For now, the restriction that the atomic orbitals be valence orbitals in point 1 is to ensure the “correct” (at the level of approximation of atomic orbitals) limiting ground- state wavefunction be

obtained at infinite atomic separation. Using other forms of the basis functions, for instance so-called “virtual orbitals” corresponding to higher principal quantum number, will lead to spurious overestimation of the atomic energies in this limit, and “bonding” orbitals formed from them will not necessarily lower the actual ground-state energy.

However, since neglecting interelectron repulsion, the atomic orbitals are all degenerate in energy for the same principal quantum number, using “virtual” orbitals in the valence shell will not lead to a large error in this limit, whereas using more than two orbitals (or other basis functions) in the linear combination leads to unnecessary complications for the student. This said, the molecular orbitals formed within this “linear combination of atomic orbitals” as the approximation is often called, should not be reified. The actual numerical solution of the Schrödinger equation needs to proceed from the Hamiltonian of the system, and cannot, in any case, be written exactly as a product of orbitals. Restricting their number to the actual number of electrons in the system does not imply that they “exist” with the same ontological status as the electrons themselves. We therefore impose no such restrictions (yet this often seems not to be the case in introductory textbooks, although not explicitly mentioned; see, for instance, the treatment in Ref. 19).

The most important reason to introduce molecular orbitals, even in the qualitative guise defined above, is that it produces a natural explanation for the special affinity observed for the electron pair. At most two electrons may follow the same spatial motions in the molecule frame. This does not mean, however, that the two electrons are always at the same place, or even close. In

fact, two electrons moving according to the same orbital will tend to avoid each other because of electrostatic repulsion. The basis for the “exchange interaction” [20] that modulates this effect somewhat need probably not concern the high school student, save for the very curious one.

Last, we introduce a fifth principle that is more approximate than the ones presented this far:

5. Electrons in atomic orbitals (as opposed to those in molecular orbitals) shield the nuclear charge of their parent atom completely, and thus contribute indirectly to the energy of the chemical bond through reduction of the internuclear repulsion.

This principle will prove useful in the examples to be discussed presently, but it should be clear that it overestimates the electrostatic shielding. We are, however, not aiming for quantitative accuracy but merely qualitative explanations.

DISCUSSION OF SOME CHOSEN EXAMPLES

It is now easy to show that H_2 , H_2^+ and H_2^- are stable species, on account of their having more bonding than antibonding electrons according to the principles above. Likewise, He_2 is proven not to exist because it is predicted to have equal numbers of bonding and antibonding electrons. However, one may fruitfully inquire about the heteronuclear diatomics HHe and HeF as prototype cases of helium compounds. At first

glance, they would seem to be erroneously predicted as stable species according to the postulates presented.

HHe

That HHe is not predicted to be a stable species becomes clear from the above principles if we consider also the electrostatic repulsion between the atomic nuclei, which we have hitherto ignored. This hypothetical species is isoelectronic with H_2^- but has twice the internuclear repulsion (given the same bond length). Alternatively, it can be compared with the more studied H_2^+ whose bond energy is 269 kJ/mol [21] and internuclear repulsion (at 1 Å, a typical bond length) of 1386 kJ/mol. In other words, the one-electron bond of H_2^+ provides roughly 1650 kJ/mol of stabilization. The stabilization energy predicted by our qualitative model for HHe will be smaller than this value on account of principle 2 above (in total, there is only one electron contributing to the bond). However, the internuclear repulsion (at 1 Å) alone is 2770 kJ/mol (there are no shielding core electrons on either atom), far in excess of the upper limit for the stabilization energy of HHe, which indicates that this species is not stable *even before we account for interelectron repulsion* which we have neglected. (Removing an electron, yielding HHe^+ with two bonding electrons, the same arguments lead to a doubling of the upper

limit for the stabilization energy of roughly 3300 kJ/mol, which exceeds the internuclear repulsion, proving the feasibility of this molecular cation.)

HeF

The case of HeF may similarly be analyzed in the same manner as HHe. The $2s$ - and $2p_z$ - orbitals on F combine with the $1s$ -orbital on He, yielding two bonding and two antibonding molecular orbitals, by the first principle. By principle 4, of the eleven electrons in the system, four enter the molecular bonding orbitals, two enter an antibonding orbital and the remaining ones remain in the atomic $2p_x$ - and $2p_z$ - and $1s$ -orbitals on F. By principle 5, these remaining electrons shield the nuclear charge of F, reducing its apparent value to $4+$. Even so, although there is an excess of two bonding electrons with respect to antibonding ones, the remaining internuclear repulsion (at 1 Å) is roughly 11000 kJ/mol, much more than twice greater than that of HHe, which we know to be unstable for half the number of excess bonding electrons. From the experimental data for H_2^+ , we know that each bonding electron provides roughly 1650 kJ/mol of stabilization, and so an excess of about seven bonding electrons would be needed for HeF to be stable.

Alkaline Earth Metals

Unlike helium, the alkaline earth metals are predicted to form dimers on account of their p -orbitals that can combine and form molecular orbitals, thus ensuring there are enough bonding orbitals to account for all the valence electrons on each atom. (According to our first principle, only atomic orbitals from the valence shell contribute to the bonding, and the helium atom has no valence p -orbitals). In fact, each alkaline earth metal dimer is predicted to have four excess bonding electrons, but this prediction overestimates the actual bond strength because it neglects the high energy of the atomic p -orbitals (see our second principle). The internuclear repulsion is modest because of shielding by the core electrons.

O₂ and HF

While it is easy to see from our principles that O₂ should have a net total of four binding electrons, in accordance with the Lewis picture of this bond, it is a failure of the Lewis model that the bond energy of HF is greater (if ever so slightly) than that of O₂, given that the former is taken to be a “single bond” whereas the latter is a “double bond”.

With the qualitative theory that we advance here, both bonds are the result of four bonding electrons [22]. This can be seen if we combine the $1s$ -orbital on the H atom twice: once with the $2s$ -orbital and once with the $2p_z$ -orbital on the F atom, both of which have the

appropriate symmetry. Indeed, the prediction does not change if we combine the $1s_{\frac{1}{2}}$ orbital on H in turn with each of the occupied orbitals on F, whether valence or core, but ignoring the core electrons contribution to the molecular orbitals is justified on account of principle 2. Moreover, it allows us, by principle 5, to treat the nuclear charge of F as an effective nuclear charge of $4+$, it being shielded by the electrons not participating in the chemical bond. According to the same arguments as before, the internuclear repulsion that the bonding electrons must overcome is then roughly 5550 kJ/mol. With four bonding electrons, it is reasonable to expect a stabilization energy at most four times that found in H^+ , that is, about 6600 kJ/mol if we neglect interelectron repulsion. This leads to a predicted upper limit for the bond strength of 1050 kJ/mol, whereas the actual value is around 550 kJ/mol [23]. The discrepancy is due partly to the neglect of interelectron repulsion, partly to the overestimation of the nuclear screening and partly to the better overlap and more similar energies of the orbitals in the homonuclear diatomic H_2^+ than in the heteronuclear HF.

What about Ionic Contributions?

One could be tempted to argue that the higher bond strength of HF is due to its supposedly large ionic character, compared to the nonpolar covalent bond in O_2 . This is an especially appealing argument at the high-school level where students are well

acquainted with the concepts of covalent and ionic bonds (and their intermediates). Indeed, the student might even reach this conclusion within the confines of the qualitative treatment presented in this paper. This type of question also illustrates the nature of theoretical explanations. What is *actually* meant by the “ionic character” of a covalent bond?

Let us briefly consider this case. A completely ionic bond would require that there be virtually no overlap between the orbitals of F and H, which is *a priori* not altogether unlikely given the strong nuclear attraction of the fluorine atom. Transferring an electron between the $1s$ -orbital on H and any “receiving” orbital on F (which then plays the role of the “molecular orbital”) amounts, in the most generous estimate (neglect of interelectron repulsion), to an energy gain equal to the difference in ionization energy between the two atoms. It would be a conceptual fault, however, to then add to this energy the ionic attraction between the resulting hydrogen and fluoride ions. According to our postulates, all electronic energy except the internuclear repulsion is included in the orbital energies and adding a Coulombic attraction between the resulting ions would amount to a double counting. For a purely ionic bond to form, the energy difference between the ionization energies must hence exceed the “residual” internuclear repulsion (that part of the internuclear repulsion that remains when the shielding effect of the non-bonding electrons has been taken into account). However, it is easily verified that even the most

conservative estimate (*i. e.*, all F-electrons except one are nonbonding) of the corresponding internuclear repulsion at bonding distances (to wit, roughly 1400 kJ/mol) greatly exceeds the difference in ionization energy between F and H (to wit, about 370 kJ/mol). This explanation is hence not admissible.

CONCLUDING REMARKS

Avoiding higher mathematics and computer simulations altogether (even indirectly), we have introduced five principles that build upon a typical high-school curriculum that covers atomic orbitals in an at least qualitative fashion. These principles allow us to discuss the chemical bonding, or lack thereof, in simple diatomics without invoking Lewis theory [24]. The foundations thus laid do not impede the further development of quantum mechanics in higher-level courses, while at the same time illustrating an alternative approach to the chemical bond than the Lewis one. In particular, because of the generalization of atomic to molecular orbitals, the enigmatic importance of the electron pair can be explained at least partly as a consequence of the Pauli exclusion principle, known to students from the *Aufbau* principle in atomic theory.

I stress once again that the point of this qualitative treatment of molecular orbital theory is as an introduction to the topic in upper secondary education in preparation for tertiary education on the topic. Establishing a simple, but firm, foundation devoid of

misconceptions is important for progressing further into the topic in later studies. At the same time, the implications according to the theory of HF having a double bond serves to challenge categorical notions of “correct” and “incorrect” science explanations that are common among high school students.

Finally, although the use of qualitative molecular orbital diagrams has been eschewed in this text for reasons of space, they are definitely pedagogically valuable in the classroom to illustrate the points and should be used liberally.

REFERENCES

1. Barke, H.-D.; Harsch, N. Bond forces versus electron pairs: two concepts for chemical bonding. *African Journal of Chemical Education* **2021**, *11*, 15–28.
2. Bacskey, G. B.; Reimers, J. R.; Nordholm, S. The mechanism of covalent bonding. *Journal of Chemical Education* **1997**, *74*, 1494.
3. Nordholm, S. Delocalization the key concept of covalent bonding. *Journal of Chemical Education* **1988**, *65*, 581.
4. Nordholm, S.; Bäck, A.; Bacskey, G. B. The mechanism of covalent bonding: Analysis within the hückel model of electronic structure. *Journal of chemical education* **2007**, *84*, 1201.
5. Ashkenazi, G.; Kosloff, R. The uncertainty principle and covalent bonding. *The Chemical Educator* **2006**, *11*, 66–76.
6. Rioux, F. The covalent bond examined using the virial theorem. *Chem Educator* **2003**, *8*, 10–12.
7. Ogilvie, J. F. The nature of the chemical bond—1990: There are no such things as orbitals! *Journal of Chemical Education* **1990**, *67*, 280.
8. Ogilvie, J. *Conceptual trends in quantum chemistry*; Springer, 1994; pp 171–198.
9. Pauling, L. The nature of the chemical bond—1992. *Journal of Chemical Education* **1992**, *69*, 519.

10. Hoganson, C. The Mechanism of Covalent Bonding. *Journal of Chemical Education* **1999**, 76, 318.
11. Gillespie, R. J.; Robinson, E. A. Gilbert N. Lewis and the chemical bond: The electron pair and the octet rule from 1916 to the present day. *Journal of computational chemistry* **2007**, 28, 87–97.
12. Gillespie, R. A defense of the valence shell electron pair repulsion (VSEPR) model. *Journal of Chemical Education* **1974**, 51, 367.
13. Erlina,; Cane, C.; Williams, D. P. Prediction! The VSEPR Game: Using cards and molecular model building to actively enhance students' understanding of molecular geometry. *Journal of Chemical Education* **2018**, 95, 991–995.
14. The limitations of this “orbital approximation” for many-electron atoms is beyond the topic of this paper.
15. Autschbach, J. Orbitals: some fiction and some facts. *Journal of Chemical Education* **2012**, 89, 1032–1040.
16. Some economy of language is however necessary, so that we will not adhere strictly to all of Autschbach's recommendations.
17. With respect to this principle, it is important to stress that the orbitals (atomic or molecular) being simply mathematical functions of the motion of the electrons, one and the same orbital (that is, function) can be used in many different combinations.
18. Atkins, P. W.; Friedman, R. S. *Molecular quantum mechanics*; Oxford university press, 2011.
19. Zumdahl, S. S.; DeCoste, D. J. *Chemical principles*; Nelson Education, 2012.
20. Jensen, F. *Introduction to computational chemistry*; John wiley & sons, 2017.
21. Bressanini, D.; Mella, M.; Morosi, G. Nonadiabatic wavefunctions as linear expansions of correlated exponentials. A quantum Monte Carlo application to H₂⁺ and Ps₂. *Chemical physics letters* **1997**, 272, 370–375.
22. We are essentially arguing that HF contains a double bond, which is an important point of disagreement with Lewis theory but more in line with the experimental data of bond strength.
23. Dibeler, V. H.; Walker, J. A.; McCulloh, K. Photoionization Study of the Dissociation Energy of Fluorine and the Heat of Formation of Hydrogen Fluoride. *The Journal of Chemical Physics* **1969**, 51, 4230–4235.
24. The existence of these diatomics does not, however, indicate that higher polyatomics may not form; whereas the nonexistence of the dimer implies that the atom is inert.

ASSESSMENT OF STATUS AND PRACTICES OF CHEMISTRY LABORATORY ORGANIZATION AND UTILIZATION IN ‘ADET’ AND ‘DEBREMEWII’ SECONDARY SCHOOLS, AMHARA REGION, ETHIOPIA

Asefa Belete¹, Teshome Mulugeta¹, Mulugeta Teshome Gebreyes^{1,2*}, and Asefa Belete¹
¹Department of Chemistry, Bahir Dar University; ²Department of Chemistry, Bonga College
of Teacher Education, Ethiopia

*Corresponding Author Email: mulerpeace@gmail.com

ABSTRACT

This study intends to assess the availability of Chemistry laboratories in schools, extent of applying laboratory and its resources in teaching chemistry subject, and the problems confronted in using chemistry laboratories in the teaching and learning process of the subject chemistry in ‘Adet’ and ‘Debremewii’ secondary school, Amhara region, Ethiopia. The study also examines the practices of organizing and utilizing chemistry laboratory in the schools. A mixed method research approach was used. The study was targeted two government higher secondary schools (‘Adet’ and ‘Debremewii’ secondary school). The respondents were all chemistry teachers, one department heads, one chemistry laboratory technicians, and 20 students from each school of grades 9 and 10. Questionnaire, Rating scales, interview and observation checklist were used to collect data for the study. The data collected was analyzed for Percentages and frequencies using Statistical Package for the Social Sciences (SPSS) version 23. The study’s findings confirmed that in both schools; there were isolated science laboratory rooms, available laboratory apparatus and chemicals are stored in an unorganized way, there are no chemistry laboratory resources available adequately, chemistry teachers and students from grade 9 and 10 hardly use chemistry laboratories, demonstration method of experimentation is the most commonly used method and students laboratory performance assessment is based on the paper and pencil methods of assessment. It was also revealed that several teachers confronted problems when performing chemistry laboratory experiments due to inadequate availability of chemistry laboratory facilities, absence of well-trained laboratory assistant, lack of appropriate skills and training of chemistry teachers, and lack of important facilities including electricity and water to the laboratory rooms were some among the others. The study recommended that different stakeholders in education sector and other concerned bodies should support secondary schools in organizing and utilizing chemistry laboratory practical activities in both schools for the effective teaching and learning of the subject. [*African Journal of Chemical Education—AJCE* 13(1), January 2023]

INTRODUCTION

The knowledge and skills of the subject Chemistry is significant in various parts of life. It is a vital subject in different professions in the education system and in the real-life situation of humankind. Especially, in the education system, including Medicine, Veterinary medicine, Nursing, Engineering and Biotechnology its role is significant. Moreover, it is also a crucial subject for the expansion of science and technology in any country. Science and technology play a central role in the modernization and growth of economic and social systems [1]. As claimed by Derkatch [2], the development of human resources in this area consequently has become a prominence in many developing countries.

Consequently, learning science, including chemistry, is an important part of primary and secondary education. In chemistry learning, laboratories have various benefits ranging from making learning actual to building foundation for science education in the succeeding levels of science learning [3]. In its nature Chemistry is an experimental science and its development and application demand experimental work [4] therefore, laboratory education plays crucial role in the education of chemistry for the growth of practical knowledge and skills of learners. In view of this fact, laboratory activity is considered to be the characteristic features of science education and particularly in chemistry education at all levels particularly, in secondary school science classes.

Particularly, Chemistry is a laboratory science and cannot be efficiently taught without a strong laboratory experience for students at any school levels. The identification, manipulation, and

general use of laboratory equipment are integral parts of the subject. Laboratory activities have long had a distinct and central role in the science curriculum as a means of making sense of the natural world. Practical chemistry, on the other hand, is an activity that involves students to either work independently or in a group in the laboratory or any place specifically assigned for carrying out an experiment and make an observation or manipulation of the real object and phenomenon. Conducting practical in chemistry is necessary bearing in mind that, the subject aims at understanding the chemical composition, nature, properties and transformation of matter [5].

The extent of adequacy of laboratory facilities for science teaching depends on the population of students in a particular school [6]. Furthermore, as mentioned by Takwate [7], the adequacy of laboratory facilities has been described to have a substantial outcome on the students' academic performance in chemistry. However, a study on the impact of the adequacy of laboratory facilities and academic performance in chemistry found that adequacy had a significant influence on students' academic performance in secondary school chemistry teaching [8].

Various research findings have shown that accessibility of teaching and learning resources make a significant contribution in performance in the Sciences. As Mwangi [9], mentioned most of the poorly performing schools spent less money on the purchase of teaching and learning resources. Masime & Masime [10] on the other hand, mentioned that there is a positive and significant relationship between students' achievement in physics and chemistry and the level of adequacy of laboratories, apparatus, chemicals and exposure of students to practical exercises. Furthermore, the

science laboratory has a direct effect on academic performance as per the instructional theory of learning interaction. As stated by Pareek [8], it is commonly supposed that constant practice leads to proficiency in what the learner learns during classroom instruction. Additionally, it is believed that the quality of teaching and learning science experiences depends on the scope of the adequacy of laboratory facilities in secondary schools and the teacher's effectiveness in the use of laboratory facilities with the aim of enabling and providing meaningful learning experiences in the learners. Besides, laboratory practices have been found to widen problem-solving abilities [11], intellectual maturity [4], scientific thinking [12], and practical skills [13].

Despite its significance of practical chemistry, developing countries are commonly characterized by a poor standard level of education which resulted from many factors, including limited budget to education, lack of trained and skilled manpower and inadequate facilities. The situation is more common in the developing countries where the inadequate amount of money allocated normally to education cannot provide to even 30% of what is required [14]. As it is well known, Chemistry without practical work is seen as a body of factual information and general laws, which conveyed nothing of lasting power to the mind [15]. The education and training policy of Ethiopia [16] states that science should be taught in a practical way. It discourages rote and memory learning. Fundamentally, the Ethiopian secondary and preparatory chemistry curriculum centers at facilitating students to solve real life problems and become independent and helpful citizens. In view of that, vital to the teaching-learning process in the secondary chemistry curriculum is practical work

directed towards mastery of scientific skills: process skills, manipulative skills and thinking skills. More distinctively, as stated by federal democratic republic of Ethiopia ministry of education [17], after completion of their upper secondary chemistry syllabi students are expected to use scientific methods in solving problems; and demonstrate an understanding of experimental skills, knowledge of laboratory procedure and scientific enquiry skills including observing, inferring, predicting, comparing and contrasting, communicating, analyzing, classifying, applying, theorizing, measuring; asking questions, developing hypotheses, performing and designing experiments, interpreting data, drawing conclusions, making generalizations and problem solving.

In this study, researchers will assess the availability of chemistry laboratories in schools, the resources available in the laboratories, extent of applying laboratory and its resources in teaching chemistry subject in ‘Adet’ and ‘Debremewii’ higher secondary school, Amhara region, Ethiopia. The school is selected on the basis of ease of access of transportation and on the basis of proximity to the researcher’s residence.

Statement of the Problem

In schools, chemistry laboratory is the most proper place for students to learn how to research, organize, clarify and measure all the sciences. Most researchers believe that practical work is a significant activity in school science. At national level, in Ethiopian school students’ achievements in chemistry subject has been low. This low achievement or performance of students in chemistry subject demonstrates that they are not meeting the expected knowledges, attitudes, and

skills as per indicated in the syllabus. Several research findings also revealed that there are aspects that can minimize students' achievements in chemistry subjects. As mentioned by Hastings & Bham [18], poor teaching methodology is one to be mentioned. Furthermore, Ndifon et. al., [19], revealed that allocation of low budget for provision of science laboratory resource is another factor for lower achievement of science subject in schools. Similarly, poor school administration and leadership, low teachers' commitment, insufficient schools' supervision [20], poor performance in practical activities [21], leads to students' low achievement in the subject chemistry.

Moreover, when the students are taught chemistry theoretically, without the practical aspects done in the laboratory, the students will not understand the abstract concepts of chemistry accurately. In order to teach the subject Chemistry practically, laboratory equipment and chemicals are vital. But they are hardly appropriately accessible due to their difficulty of obtainability and their expensive cost. As a result, many secondary schools could not conduct practical chemistry experiments as expected and stated in the textbooks. Additionally, the researchers' many years of teaching chemistry and close observation of secondary schools revealed that the current practice of chemistry laboratory organization and utilization is not satisfactory and to the expected standard as stated in chemistry curriculum. Moreover, assessment of the practice of organizing, designing, equipping, and utilizing chemistry laboratories is not conducted in these schools or there is very little if any, empirical data on the contributions of Chemistry laboratory which is a very vibrant necessity for teaching chemistry to the achievement levels in the subject at various levels. This research,

therefore, attempts to assess chemistry laboratory status and practices in ‘Adet’ and ‘Debremewii’ higher secondary school, Amhara Region, Ethiopia to make its support by filling this gap.

Objectives of the Study

The general objective of the study is to evaluate chemistry laboratory status and practices in ‘Adet’ and ‘Debremewii’ higher secondary school, Amhara Region, Ethiopia.

Specifically, the study desires;

- i) To examine the extent of availability and adequacy of chemistry laboratory resources (laboratory room, equipment, apparatus, and chemicals) existing in ‘Adet’ and ‘Debremewii’ higher secondary school, Amhara Region, Ethiopia.
- ii) To evaluate how chemistry laboratory apparatus and chemicals are stored in ‘Adet’ and ‘Debremewii’ higher secondary schools, Amhara Region, Ethiopia.
- iii) To investigate how chemistry teachers and students use laboratories in the teaching and learning of chemistry in ‘Adet’ and ‘Debremewii’ higher secondary school, Amhara Region, Ethiopia.
- iv) To diagnose the type of laboratory experimentation is commonly used (engaging students individually, doing experiments in parallel groups, demonstration, or others) and to point out why this/these methods are being used in these schools.

- v) To survey how teachers assess students' laboratory performance and examine which Bloom's taxonomy of learning domains (cognitive, affective or psychomotor) components are measured in the schools under study.
- vi) To point out problems confronted in using chemistry laboratories in the teaching and learning process of the subject chemistry in the schools under investigation.

Research Questions

This study is organized to answer the following questions:

- i) Which chemistry laboratory resources are available adequately in the schools' chemistry laboratory?
- ii) How are chemistry laboratory apparatus and chemicals stored in Adet' and 'Debremewii' higher secondary schools, Amhara Region, Ethiopia?
- iii) How do chemistry teachers and students of grades 9 and 10 use chemistry laboratories in the teaching and learning process of the subject chemistry in the schools?
- iv) What type of laboratory experimentation is commonly used (engaging students individually, doing experiments in parallel groups, demonstration, or others) in these schools and why?
- v) How do teachers assess students' laboratory performance and which Bloom's taxonomy of learning domains (cognitive, affective or psychomotor) components are measured?

- vi) What are the problems confronted in using chemistry laboratories in the teaching and learning process of the subject chemistry of grades 9 and 10 in the schools under the study?

MATERIALS AND METHODS

The study context

In Ethiopia, secondary schools' chemistry is one of the subjects being given to students. In the secondary school chemistry curriculum document, the subject chemistry is expected to be delivered both theoretically and using students' hand-on activities. In most secondary schools of Ethiopia, chemistry laboratories are inadequately, and poorly organized. Hence, the practice, utilization and challenges of using chemistry laboratory is highly questionable. Moreover, due to absence of proper utilization of practical teaching of the subject chemistry, students' achievement in chemistry subject in secondary school is believed to be poor. Therefore, the study is aimed to assess the status and practices of chemistry laboratory organization and utilization in 'Adet' and 'Debremewii' Higher Secondary schools, Amhara Region, Ethiopia.

Research Method

In the study, A mixed research approach specifically, descriptive survey technique was employed. Mixed research approach was employed as the advantage arose in using both quantitative and qualitative designs. As Creswell and Zhang [22], noted though the basis for employing mixed designs is varied, they can be generally described as methods to expand the scope or breadth of

research to counterbalance the weaknesses of either approach alone. Moreover, as mentioned by Mugenda and Mugenda [23], a survey design is employed to collect data from members of a population in order to determine the existing status of that population with respect to one or more variables. The study used survey design was adopted since it involved collecting data in order to answer questions regarding the current status of focus of the study.

Furthermore, survey design permits the use of numerous instruments including questionnaires, an interview schedule and an observation schedule. The study used questionnaires, an interview schedule and an observation schedule to obtain both qualitative and quantitative data from students, teachers, heads of science departments and laboratory technicians regarding the practice and utilization of Chemistry laboratories in ‘Adet’ and ‘Debremewii’ Higher Secondary schools, Amhara Region, Ethiopia.

Research design

In order to conduct the present study, triangulation design: most common and well-known approach to mixing methods [24], whose purpose is “to obtain different but complementary data on the same topic” to best understand the research problem was applied.

Sample and Sampling Technique

In the case of this specific research, purposive sampling was employed to select science teachers in these schools because they are the ones who are responsible in teaching science subjects. Heads of departments were selected for virtue of their position as they directly related to the use of

laboratory. Heads of schools were selected due to their position as they are in charge of these schools and whose administrative functions were to ensure that the implementation curriculum in their schools take place. According to Kombo & Tromp [25], purposive sampling is the procedure where the researcher purposively targets groups of people believed to be reliable for the study.

In the case of this specific research, ‘Adet’ and ‘Debremewii’ higher secondary schools, Amhara Region, Ethiopia was selected, and grades 9 and 10 chemistry subject was the target of the study.

The population for the study was 22 (Male =18 and Female= 4) and 4 (Male =4 and Female= 0) chemistry teachers, department heads (one from each school), directors (one director and one vice director from each school), and 60 (Male =32 Female= 28) and 28 (Male =16 and Female= 12) students from ‘Adet’ and ‘Debremewii secondary schools of grades 9 and 10 respectively. Hence, from both schools 26 chemistry teachers (Male = 22 and Female = 4), two department heads (both males), two directors (both males), two vice directors (both males) and 88 students (Male = 48 and Female= 30) were participated in providing data for the study. In the case of taking samples from students simple random sampling was used. In other cases, there was no sampling because the population was considerable for the study.

Table 1: Population and Sample Size of Respondents

| Selected school | Chemistry Teachers | | | Department heads | Directors | Vice Directors | Students | | | Total |
|-----------------------------|--------------------|--------|-----------|------------------|-----------|----------------|----------|--------|-----------|------------|
| | Male | Female | Total | | | | Male | Female | Total | |
| ‘Adet’ secondary school | 18 | 4 | 22 | 1 (Male) | 1 (Male) | 1 (Male) | 32 | 28 | 60 | 85 |
| Debremewii Secondary school | 4 | 0 | 4 | 1 (Male) | 1 (Male) | 1 (Male) | 16 | 12 | 28 | 35 |
| Total sample size | 22 | 4 | 26 | 2 | 2 | 2 | 48 | 40 | 88 | 120 |

In this study, in both schools all chemistry teachers, all directors and vice directors are taken as a sample. But students from both schools were determined and representative samples were taken to proceed with the study.

Data Collection Techniques and Instrumentations

Since the methodology employed in the research is mixed methods, both quantitative and qualitative data are gathered. Based on the methodology and the design selected, the quantitative data are collected by survey questionnaire & rating scale design and the qualitative data are collected by interview & observation checklist guide in a sequential model. Thus, survey questionnaire, rating scale design, interview, and observation checklist techniques was be employed.

The instrument used was on a five-point rating scale with numerical values of strongly agree (SA (5), Agree (A (4), neither agree nor disagree (NAD (3), disagree (DA (2) and strongly disagree

(SD (1). The instrument was validated by experts or teachers in chemistry teaching and measurement and evaluation. The questionnaire was distributed to the chemistry teachers. There was 100% return and the data gathered were analyzed using frequency percentage.

The instrument for data collection was both structured and unstructured questionnaire. The questionnaires were divided into two sections. The first section centered on the personal data of the respondents, while section-II is established based on the research questions. The items in section-II of the questionnaire were structured on an adapted five-point Likert scale. The research instruments were exposed to validation by two chemistry teachers and experts. Their suggestions given was included in the final copy of the instrument. The data collected were analyzed and interpreted using frequency distribution to answer the research questions. This particular research used various instruments, including questionnaires, observation schedule, rating scales and interview schedule.

Validity and Reliability of Research Instruments

For the purpose of discovering that the tools measured what they were intended to measure, the researcher employed the use of experts who were qualified in chemistry and skilled in measurement and evaluation. The expert's judgment helped to improve the content validity of research instruments.

Data Analysis

Data was collected on variables such as resources available and their adequacy, availability of laboratory technicians, activities done in the laboratory, and teachers and students' participation

in the laboratory methods of teaching, and challenges faced in using chemistry laboratories in both schools Adet' and 'Debremewii' higher secondary schools, Amhara Region, Ethiopia.

For data analysis, both quantitative and qualitative methods to analyze various data sets acquired for this study was utilized and both quantitative and qualitative data are analyzed separately and assorted at the discussion stage. Moreover, the data analysis started from the quantitative data collected by questionnaire and rating scale. Finally, the qualitative results gathered by interview and observation checklist was analyzed via narration following the themes was formed considering the nature of the evidence.

The data which were found from diverse sources were systematized in a way suitable for responding to the research questions. The researcher used SPSS version 23 software to calculate frequency counts and percentages to analyze the data from close-ended questions. The findings were related to each research question were examined and discussed in relation to the review literature. Descriptive statistics namely percentages, and frequency distribution were used to describe the data and conclusions were drawn on the basis of the analyzed data and recommendations are made based on the conclusions.

DATA PRESENTATION AND ANALYSIS

For this particular study, both quantitative and qualitative data were collected. The data gathered were presented and analyzed successively. Initial analysis of quantitative data was followed

by qualitative interview analysis. For convenience, the summary of the quantitative data gathered from each sample textbook is presented in a table.

Demographic Background

Demographic Characteristics of Chemistry Teachers

Table 2 below describes information about respondents' characteristics related to sex, qualification, and experiences.

Table 2: Demographic characteristics of chemistry teachers

| Categories | | Frequency | Percent |
|----------------|-------------------------------|-----------|---------|
| Schools | 'Adet' secondary school | 1 | 50 |
| | 'Debremewii' secondary school | 1 | 50 |
| | Total | 2 | 100 |
| Sex | Male | 22 | 84.6 |
| | Female | 4 | 15.4 |
| | Total | 26 | 100 |
| Qualifications | B.Sc./BA/B.Ed | 25 | 96.2 |
| | M.Sc./MA/M.Ed | 1 | 3.8 |
| | Total | 26 | 100 |
| Experiences | Less than 5 years | 0 | 0 |
| | 5 – 10 years | 5 | 19.2 |
| | Greater than 10 years | 21 | 80.8 |
| | Total | 26 | 100 |

The primary aim of this study was to assess the practice, organization, utilization, and problems related to the secondary school's chemistry laboratory in 'Adet' and 'Debremewii' secondary schools. Various tools of data gathering instruments were employed to obtain reliable evidence on the study area. The findings were explained under the following sub sections.

RESULTS

The result of this investigation is presented below based on the research questions of the study.

Research question one:

Adequate availability of Chemistry Laboratories resources

Chemistry teachers, department heads, directors, and students from grades 9 and 10 were given a five-point Likert scale and their responses are analyzed below.

Table 3: Frequency and Percentage of Adequate availability of chemistry laboratory resources in ‘Adet’ and ‘Debremewii’ secondary schools

| S/N | Schools | Laboratory Resources | Respondent (N) | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Decision |
|-----|-------------------------------|--|----------------|-------------------|-------|----------|------|---------|------|-------|------|----------------|------|---------------|
| | | | | Freq | % | Freq | % | Freq | % | Freq | % | Freq | % | |
| 1. | ‘Adet’ secondary school | Laboratory room avail. | 82 | 0 | 0 | 0 | 0 | 1 | 1.2 | 1 | 1.2 | 80 | 97.6 | Available |
| 2. | | Adequate chemicals available | 82 | 78 | 95.1 | 3 | 3.7 | 1 | 1.2 | 0 | 0 | 0 | 0 | Not Available |
| 3. | | Adequate apparatuses available | 82 | 76 | 92.7 | 4 | 4.9 | 2 | 2.4 | 0 | 0 | 0 | 0 | Not Available |
| 4. | | Adequate laboratory furnitures available | 82 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 39.1 | 50 | 60.9 | Available |
| 5. | | Electricity supply available | 82 | 0 | 0 | 0 | 0 | 0 | 0 | 55 | 67.1 | 27 | 32.9 | Available |
| 6. | | Water supply available | 82 | 70 | 87.5 | 10 | 12 | 2 | 2.5 | 0 | 0 | 0 | 0 | Not Available |
| 1. | ‘Debremewii’ secondary school | Laboratory room avail. | 32 | 0 | 0 | 0 | 0 | 2 | 6.25 | 10 | 31.2 | 20 | 62.5 | Available |
| 2. | | Adequate chemicals available | 32 | 30 | 93.75 | 2 | 6.25 | 0 | 0 | 0 | 0 | 0 | 0 | Not Available |
| 3. | | Adequate apparatuses available | 32 | 29 | 90.6 | 3 | 9.4 | 0 | 0 | 0 | 0 | 0 | 0 | Not Available |
| 4. | | Adequate laboratory furnitures available | 32 | 0 | 0 | 0 | 0 | 4 | 12.5 | 21 | 65.6 | 7 | 21.8 | Available |
| 5. | | Electricity supply available | 32 | 29 | 90.6 | 0 | 0 | 3 | 9.4 | 0 | 0 | 0 | 0 | Not Available |
| 6. | | Water supply available | 32 | 32 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Not Available |

The data in table 3 displays that 81 (98.8%) and 30 (93.75%) of respondents have confirmed as ‘Adet’ and ‘Deberemewii’ secondary school have laboratory rooms or buildings respectively.

The researcher also conducted an observation to discover the number of laboratory buildings in each school and how they are prearranged for several uses. The surveying of chemistry laboratory also revealed that one chemistry laboratory room occurs in each school under investigation. Furthermore, in regards to the availability of basic chemicals and apparatuses to conduct grades 9 and 10 chemistry practical activities, 78 (95.1%) and 30 (93.75%) of respondents confirmed that there are no adequate chemicals in both secondary schools of ‘Adet’ and ‘Deberemewii’ respectively. Besides 76 (92.7%) and 29 (90.6%) respondents also indicated ‘Adet’ and ‘Deberemewii’ secondary schools don’t have adequate chemistry laboratory chemicals for the level of grades 9 and 10 chemistry correspondingly.

As described in the methodology section of this study, to strengthen the quantitative data collected sample students, chemistry department heads, and school directors were interviewed to collect qualitative data. The participants of the interview have also expressed as both schools don’t have adequate chemistry laboratory chemicals and apparatuses to run practical chemistry activities in the schools’ laboratory. They additionally, said that:

The chemistry department, chemistry teachers, and students are continually requesting the schools to have adequate laboratory resources including chemicals, apparatus and materials and intern schools are frequently asking concerned officials to make them avail adequately. But, for years the problem continues to exist and teachers and schools are forced to teach the subject chemistry on theoretical basis only. (Interviewee 1, May 6, 2022).

The researcher's observation also approves the ideas given by the interviewee and the quantitative data presented above in table 3.

The complete analysis of the data on availability of laboratory and laboratory resources illustrates that both 'Adet' and 'Debremewii' secondary schools have chemistry laboratories as buildings. Moreover, the findings displayed that there was no adequate chemicals and apparatuses in the schools. From this it is known that teaching the subject chemistry using experimentation is not being carried out. But it is believed that a laboratory should be properly equipped if it is to serve its purpose [26].

The table also illustrates the availability of chemistry laboratory furnitures, electricity and water supplies in the school laboratories. The data obtained from the respondents (Chemistry teachers, department heads, directors, and students from grades 9 and 10) clearly confirmed that both 'Adet' and 'Debremewii' secondary schools have laboratory furnitures including desks, chemical store shelves, blackboards, chairs, and tables as the data from respondents 82 (100%) and 28 (87.4%) revealed respectively. In regard to, the supply of electricity to the chemistry laboratory 82 (100%) of respondents from 'Adet' secondary schools mentioned as there is an electricity supply and in contrary 29 (90.6%) of respondents from 'Debremewii' secondary school revealed that the chemistry laboratory in the school doesn't have an electric supply. Similarly, respondents stated that the water supply is the same as that of water.

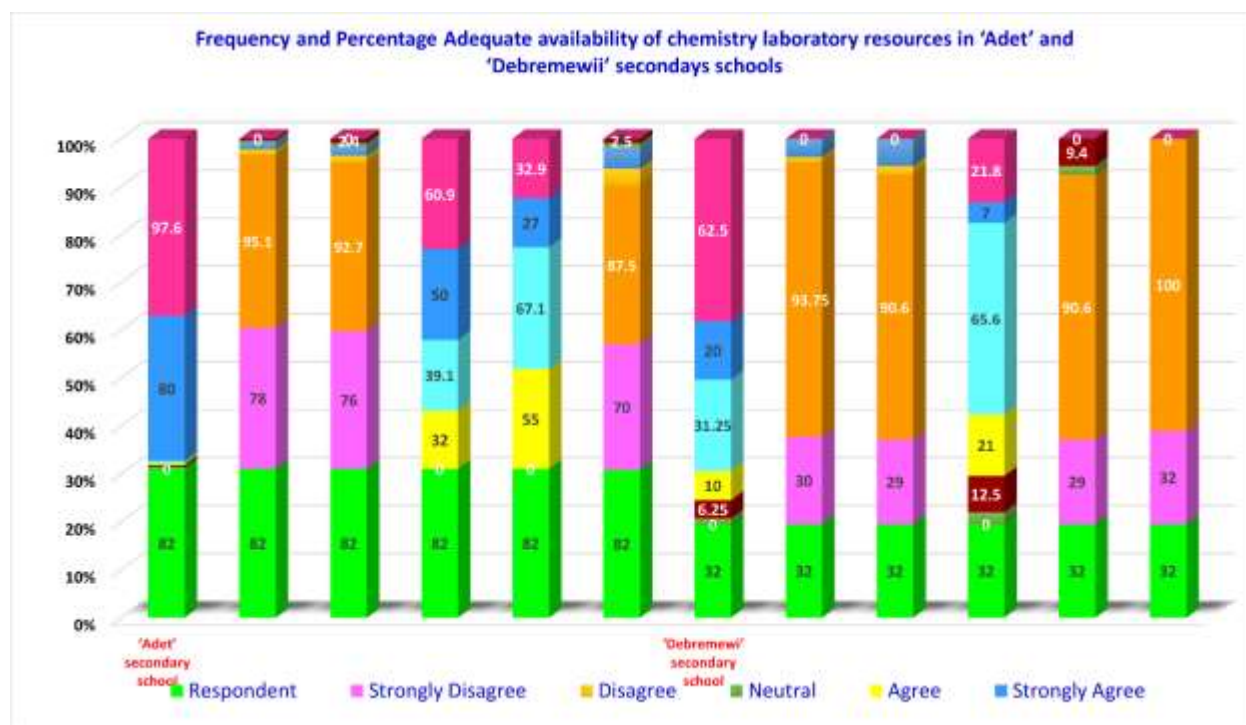


Figure 1. Frequency and Percentage Adequate availability of chemistry laboratory resources in 'Adet' and 'Debremewii' secondary schools.

The finding of this study showed that there are schools within Amhara Region, Ethiopia, still today that do not have chemistry laboratories in secondary schools. In one of these schools, 'Debremewii' secondary school there is no a single chemistry laboratory activity shown to students. But, very little practical work, mostly of the form of teacher demonstration was said to be taking place in 'Adet' secondary school.

Hence, it can be deduced that teaching chemistry with inadequate laboratory or in the absence of laboratory supported teaching is one of the key causes of students' poor achievement in chemistry in Amhara Region, Ethiopia. The finding of this study is in agreement with several other research findings. Among these, Millar [27], described that schools with no laboratories were poor with human and material resources and are likely to affect student's achievement in Chemistry. Furthermore, as stated by Lewis [28], engaging students in practical activity boosts learning by allowing learners to share ideas and experiences within their groups.

Research question two:**The way Chemistry laboratory apparatus and chemicals stored in schools**

Chemistry teachers (Adet = 22, Debremewii = 4), Department heads (one from each school), Directors (one from each), and Vice directors (one from each) were subjected to respond the techniques used to store laboratory chemicals and apparatuses that are available in the school.

Table 4: Frequency and Percentage of methods of chemicals and apparatuses arrangement in the laboratory in ‘Adet’ and ‘Debremewii’ secondary schools

| Schools | Items/Determinant factor | Respondents (N) | Organized based on scientific ways | | Organized but not in a scientific way | | Stored in a random way | | Decision |
|-------------------------------|--|-----------------|------------------------------------|---|---------------------------------------|------|------------------------|------|---------------------------------------|
| | | | Frequency | % | Frequency | % | Frequency | % | |
| ‘Debremewii’ Secondary school | Approaches in which the available chemicals are stored | 7 | 0 | 0 | 6 | 85.7 | 1 | 14.3 | organized but not in a scientific way |
| | Methods in which the available apparatuses are stored | 7 | 0 | 0 | 7 | 100 | 0 | 0 | organized but not in a scientific way |
| ‘Adet’ Secondary school | Approaches in which the available chemicals are stored | 25 | 0 | 0 | 23 | 92 | 2 | 8 | organized but not in a scientific way |
| | Methods in which the available apparatuses are stored | 25 | 0 | 0 | 24 | 96 | 1 | 4 | organized but not in a scientific way |

However, there are no adequate chemistry laboratory chemicals and apparatuses in both schools, under this research question the approaches used to store already existing chemicals and apparatuses were studied. Findings from the above table 4 shows that in both schools the technique used to store chemicals and apparatuses were organized but the organization is not on the basis of rules and regulations of chemicals and apparatus placement.

The observation made by the researcher also like the conclusion of the above table. Specifically, the researcher observed that improper labelling of chemicals, wrong storage of reactive

chemicals, for instance acids are stored closer to bases in Adet secondary school. Additionally, the researcher observed that glassware sets are placed with metals hence, the glassware can easily get broken.

Therefore, it can be deduced that the already existing chemicals and apparatuses were organized or isolated, but the organization was not based on the rules and regulations of apparatuses and chemicals storage.

Research question three:

Chemistry teachers and students' extent of utilization chemistry laboratories for teaching and learning the subject chemistry in the schools

Chemistry department heads, teachers, directors, and vice directors, from each school were questioned to respond questionnaire, fill the rating scale, and conduct an interview with the researcher on extent of utilization chemistry laboratories and type of experimentation used in teaching chemistry in 'Adet' and 'Debremewii' secondary schools.

Table 5: Frequency and Percentage of extent of utilization chemistry laboratories and type of experimentation used in teaching chemistry in ‘Adet’ and ‘Debremewii’ secondary schools

| S/N | Scho | Items | Resp on(N | Responses | Calculations | | Conclusion | |
|-----|--|--|--|------------------------------------|----------------|------|--|--|
| | | | | | Frequ. | % | | |
| 1. | ‘Debemawii’ Secondary School | Laboratory session time table is prepared and used | 7 | Yes | 2 | 28.6 | Laboratory session time table is not prepared and used | |
| No | | | | 5 | 71.4 | | | |
| 2. | | How often do you use chemistry laboratory for teaching chemistry | 7 | Once in a week | 0 | 0 | Laboratory is used for teaching once in a semester | |
| | | | | At the end of each unit | 0 | 0 | | |
| | | | | Once in a semester | 7 | 100 | | |
| | | | | Once in a year | 0 | 0 | | |
| | | | | Not at all | 0 | 0 | | |
| 3. | | What method/strategy do you usually, use in teaching chemistry in the laboratory | 7 | Students’ independent activity | 0 | 0 | Demonstration methods of teaching is the most commonly used lab. Teaching method | |
| | | | | Small group activity | 0 | 0 | | |
| | | | | Demonstration | 7 | 100 | | |
| | | | | Large group activity | 0 | 0 | | |
| | | | | No laboratory session is conducted | 0 | 0 | | |
| 1. | | Adet’ Secondary School | Laboratory session time table is prepared and used | 25 | Yes | 0 | 0 | Laboratory session time table is not prepared and used |
| No | | | | | 25 | 100 | | |
| 2. | | | How often do you use chemistry laboratory for teaching chemistry | 25 | Once in a week | 0 | 0 | Chemistry laboratory is not used at all. |
| | At the end of each unit | | | | 0 | 0 | | |
| | Once in a semester | | | | 0 | 0 | | |
| | Once in a year | | | | 0 | 0 | | |
| | Not at all | | | | 25 | 100 | | |
| 3. | What method/strategy do you usually, use in teaching chemistry in the laboratory | | 25 | Students’ independent activity | 0 | 0 | Chemistry laboratory is not used at all. | |
| | | | | Small group activity | 0 | 0 | | |
| | | | | Demonstration | 0 | 0 | | |
| | | Large group activity | | 0 | 0 | | | |
| | | No laboratory session is conducted | | 25 | 100 | | | |

From table 5, it is observed that the percentage of absence of laboratory session timetable is larger. 71.4 % of respondents from ‘Debremewii’ secondary school and 100% of the other

respondents from ‘Adet’ secondary school confirmed that there is no laboratory session time table prepared and used in the school. In regards to the extent of using chemistry laboratory for practical teaching of students, 100% of respondents described as they used the school laboratory once in a semester and 100% of the other respondents mentioned as they never use the chemistry laboratory at all for practical teaching of the subject chemistry in ‘Debremewii’ and ‘Adet’ secondary schools respectively.

The interview made with chemistry department heads of the schools, and the directors and vice directors also in agreement with the above data and findings. Interviewees revealed that the departments in both schools don’t have already scheduled timetable. Additionally, interviewees from ‘Adet’ secondary school mentioned that chemistry teachers plan their own time and brings students to the laboratory once in a semester. Similarly, the interviewees from ‘Debremewii’ secondary schools declared that chemistry teachers totally were not using the school chemistry laboratory as there is lack of necessary chemicals and apparatuses in the school.

In addition to the above result, the researcher observations also assured that in the two schools timetable for conducting chemistry laboratory sessions were not arranged and in ‘Adet’ secondary school chemistry teachers document indicated as they have conducted one laboratory session (2 hours in this specific case) for grades 9 and 10 students. The researcher observation of

‘Debremewii’ secondary verified as chemistry teachers were not using the chemistry laboratory for the whole academic year.

It can therefore be concluded that in both secondary schools, laboratory session time table is not prepared and utilized for teaching chemistry using numerous experiments and hands-on activities. Moreover, the extent in which chemistry teachers use experimental methods of teaching the subject chemistry is very low. As mentioned by Muchai & Twoli [29], learning in any science laboratory is a hands-on experience and in a laboratory setting, students use laboratory chemicals, reagents, and various apparatus to operate materials, gather data, make inferences and interconnect the results and their findings.

Research question four:

Type of laboratory experimentation is commonly used in schools

Through the researcher was planned to conduct the actual chemistry teaching sessions in both schools, teachers in ‘Debremewii’ secondary school already revealed that they were not teaching chemistry using the laboratory and chemistry teachers in ‘Adet’ secondary schools informed the researcher as they don’t have sessions recently. Therefore, the researcher asked theses chemistry teachers to explain what method/strategy do they usually, use in teaching chemistry in the laboratory? They verified as demonstration method of teaching is the only method used to teach chemistry in their teaching. They also elucidated the reason why they were depending on this method

and mentioned that absence of adequate laboratory facilities is one among others. Additionally, they described that this method helps them to save time: two or three practical activities can be conducted in short time.

The findings displayed in Table 5 above also showed that almost all (100%) of ‘Adet’ and ‘Debremewii’ secondary schools respondents revealed that the method or strategy employed to teach chemistry practically is demonstration and no laboratory sessions was conducted respectively in these schools.

In conclusion, the findings therefore showed that there was no any laboratory-based teaching of the subject chemistry in ‘Debremewii’ secondary school and even in ‘Adet’ secondary school where there was a laboratory session conducted once in a semester demonstration was the commonly employed method. As mentioned by the school chemistry teachers, inadequate chemistry laboratory facilities and the advantage of demonstration method to conduct two or three practical activities within short time were the reasons stated.

The involvement of students, the teacher or both in the laboratory activity

The researcher’s critical observation, the data obtained from Table 5 above, and interviewees’ explanation proved that in ‘Debremewii’ secondary school there was no learners’ engagements in the laboratory activities as there was no practical activity conducted in the school. But, in ‘Adet’ secondary school as mentioned above, the various data collected indicated that

demonstration is the typical method used in laboratory teaching in the school. In employing teacher demonstrated laboratory method, teachers reveal the real experiments or scientific investigations to enlighten science lessons to the class using limited set of laboratory equipment and materials.

Hence, in the case of this particular study students were not engaged actively in laboratory experimentation in both schools. In the case of ‘Adet’ secondary school teachers are highly involved in the preparation, conducting the actual experiment to be demonstrated and students participated in an observation of teacher’s demonstration task.

Research question five:

Students’ laboratory performance assessment in relation to Bloom’s taxonomy of learning domains (cognitive, affective or psychomotor) components.

Table 6: Frequency and Percentage of students' laboratory performance assessment in relation to Bloom's taxonomy of learning domains in chemistry laboratory teaching

| S/N | School | Items | Respon (N) | Responses | Calculations | | Conclusion |
|-----|-----------------------|---|---------------|-----------|--------------|-------------|------------|
| | | | | | Frequ. | % | |
| 1 | Secondary School | The teacher identifies the cognitive, affective, and psychomotor domains of the laboratory activity before conducting the laboratory session | 7 | Yes | 1 | 14.3 | |
| | | | | No | 6 | 85.7 | |
| 2 | | Students' laboratory performance is assessed using rubric designed at department level. | 7 | Yes | 0 | 0 | |
| | | | | No | 7 | 100 | |
| 3 | | Students' different laboratory performance (cognitive, affective, and psychomotor domains) are assessed separately as per the objectives of the task. | 7 | Yes | 0 | 0 | |
| | | | | No | 7 | 100 | |
| 4 | | Students' laboratory performance is assessed using paper and pencil exams separately from the theoretical aspects. | 7 | Yes | 1 | 14.3 | |
| | | | | No | 6 | 85.7 | |
| 5 | | Students' Laboratory performance is not separately assessed in the school. | 7 | Yes | 7 | 100 | |
| | | | | No | 0 | 0 | |
| 1. | Adet Secondary School | The teacher identifies the cognitive, affective, and psychomotor domains of the laboratory activity before conducting the laboratory session | 25 | Yes | 0 | 0 | |
| | | | | No | 25 | 100 | |
| 2. | | Students' laboratory performance is assessed using rubric designed at department level. | 25 | Yes | 1 | 4 | |
| | | | | No | 24 | 96 | |
| 3. | | Students' different laboratory performance (cognitive, affective, and psychomotor domains) are assessed separately as per the objectives of the task. | 25 | Yes | 0 | 0 | |
| | | | | No | 25 | 100 | |
| 4. | | Students' laboratory performance is assessed using paper and pencil exams. | 25 | Yes | 2 | 8 | |
| | | | | No | 23 | 92 | |
| 5. | | Students' Laboratory performance is not separately assessed in the school | 25 | Yes | 24 | 96 | |
| | | | | No | 1 | 4 | |

The results in Table 6 show that in both secondary schools, ‘Adet’ secondary school (100%) and ‘Debremewii’ secondary school (85.7%) chemistry teachers were not identifying the cognitive, affective, and psychomotor domains of the laboratory activities included in grades 9 and 10 students chemistry textbooks before conducting the laboratory session. Both chemistry teachers in ‘Adet’ (96%) and ‘Debremewii’ (100%) secondary school teachers were not used students’ laboratory assessment rubric to assess the laboratory performance of students in chemistry laboratory. Additionally, in both schools (100%) chemistry teachers were not measuring students’ diverse laboratory performance (cognitive, affective, and psychomotor) domains as per the objectives of each of specific tasks. In the same way, in both schools in ‘Adet’ (96%) and ‘Debremewii’ (100%) secondary schools the students’ laboratory performance was not distinctly assessed.

Moreover, the result of interview revealed that students’ laboratory performance was not practiced in both schools. The respondents from both schools (department heads, vice directors and the director of the schools) mentioned that chemistry teachers in both schools were not acquainted with the concept of performance assessment. They also added that the extent of using chemistry laboratory is either nil or once in a semester in the academic year.

It can therefore be concluded that in ‘Adet’ and ‘Debremewii’ secondary schools the students’ chemistry laboratory performance was not assessed. But it is generally known that by

engaging students in authentic laboratory performance assessments, opportunities are provided for them to construct meaning and to internalize new ideas and concepts.

Research question six:

Problems confronted in using chemistry laboratories in the teaching and learning the subject chemistry in the schools

This section of the analysis was to examine the understandings of chemistry teachers, department heads, directors, and vice directors on the aspects that influence the effective utilization of chemistry laboratory activities in teaching the subject chemistry the secondary schools under investigation. Respondents were allowed to select more than one options when they thought that the stated description is problem confronted in using chemistry laboratory. Therefore, the following items have been recognized in the study and the answers of chemistry teachers, department heads, directors, and vice directors were presented, analyzed, and interpreted below.

Table 7. Problems confronted in using chemistry laboratories

| S/N | Item descriptions | Participants | Respondents (N=32) | Percentages | Remarks |
|-----|---|---|-----------------------|-------------|---------|
| 1. | Teacher's lack of skills to conduct laboratory activity | ✓ Total Chemistry teachers from both schools = 26 ✓ Chemistry department heads = 2 | 20 | 62.5 | |
| 2. | Lack of time table to run laboratory activities | | 5 | 15.6 | |
| 3. | Lack of adequate chemicals and apparatus | | 31 | 96.9 | |
| 4. | Lack of students' interest and motivation | | 4 | 12.5 | |
| 5. | Lack of electricity supply to the laboratory rooms | | 28 | 87.5 | |
| 6. | Lack of water supply to the laboratory. | | 25 | 78.1 | |

| | | | | | |
|----|---|--|----|------|--|
| 7. | Absence of appropriate trained laboratory technician or attendant | ✓ Directors from both schools = 2 | 27 | 84.4 | |
| 8. | Absence of teachers' commitment | ✓ Vice directors from both schools = 2 | 2 | 6.3 | |

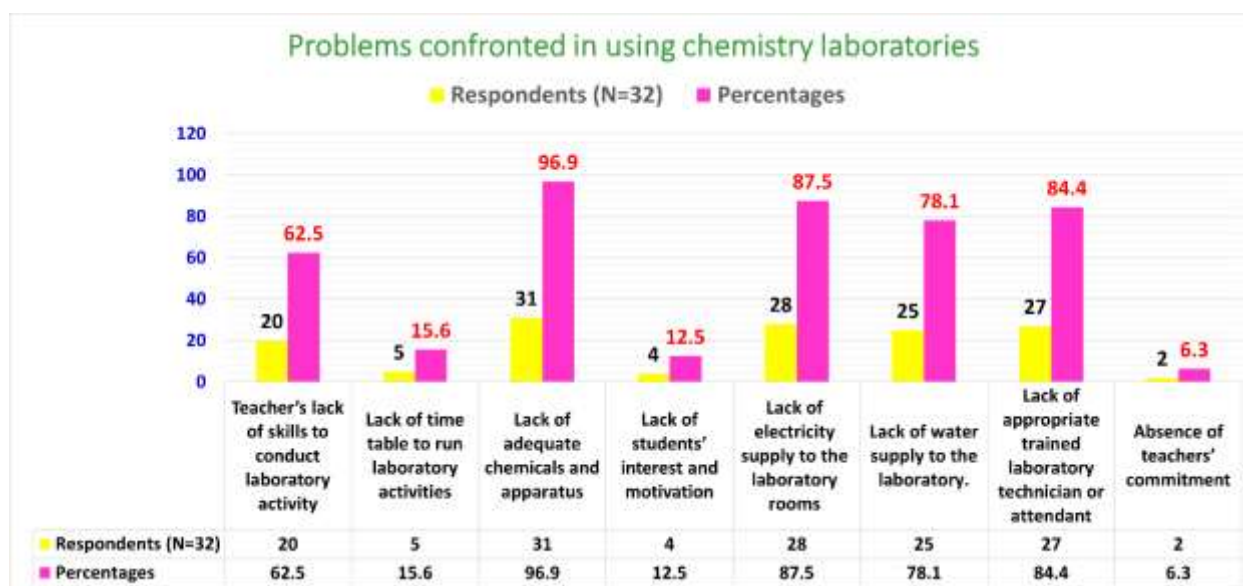


Figure 3: Problems confronted in using chemistry laboratories

In figure 3: the response indicates that lack of adequate chemicals and apparatus (96.9%), absence of appropriate trained laboratory technician or attendant (84.4%), teacher's lack of skills to conduct laboratory activity (62.5%), and lack of electricity and water supply to the laboratory rooms (87.5 %) and (78.1%) respectively are the identified problems that hindered the effective chemistry laboratory usage in both schools.

Additionally, in replying to interview and open-ended questions, as replied by respondents, there were several problems that faced in effective utilization of practical activities in both schools.

The crucial once was inadequate availability of chemistry laboratory facilities in the schools, absence of well-trained laboratory assistant in schools, lack of appropriate skills and training of chemistry teachers in both schools, and lack of important facilities for instance, electricity, water to the laboratory rooms were some among the others.

Consequently, it can be concluded that lack of adequate chemicals and apparatus, absence of proper trained laboratory technician, teacher's lack of skills in laboratory organization, utilization, and applying different teaching strategies in laboratory activity, and lack of electricity and water supply to the laboratory rooms are the utmost difficulties of 'Adet' and 'Debremewii' secondary schools, Amhara Region, Ethiopia.

DISCUSSIONS

In this particular study, the status and practices of chemistry laboratory organization and utilization in 'Adet' and 'Debremewii' Secondary schools, Amhara Region, Ethiopia was studied. On the first research question on this study, it was aimed to examine the adequate availability of Chemistry Laboratories resources in both schools. The fundamental finding of this study is that, in the context of the school's chemistry laboratory chemicals and apparatuses that are relevant to teach grades 9 and 10 chemistry were not adequately available in both schools. This finding is consistent with the findings of previous research: Barrow's [30], Onipede [31], and Ihuarulam [32], who in their distinct studies stated that science education is faced with the challenges of lack of resources

with majority of the secondary schools having no real laboratory. Additionally, Akpan [33], strongly believed that scarcities of laboratory facilities could have thoughtful implications on the learning and academic achievement of students. Moreover, Nkwocha [34], who opined, that without laboratory facilities teaching and learning of science will not take place effectively.

Similarly, Anyadiegwu [35], mentioned that there is lack of appropriate laboratory facilities that are suitable and suitable for Nigerian schools. Moreover, Niyitanga et al. [36], stated that lack of adequate funding in education is a barrier to availability of laboratory facilities in public secondary school and unavailability of laboratory facilities creates difficulty to science teachers' real delivery of concepts. Besides, the findings of Muse [35], revealed that unavailability of teaching facilities affects actual delivery of science, technology and mathematics in general.

According to Anyadiegwu [3], adequate laboratory instructional facilities are required in schools to minimize the challenges of science teachers in schools. In the same way, Etiubon [38], observed that the fulfillment of laboratory facilities in schools marks an improved efficiency of the educational development and results in improved proficiency through boosted human capacity as this facilitates acquisition of basic knowledge and skills for laboratory experiment and lifelong development. Similarly, the findings of Eze [39], supported the above findings when he described those physical facilities such as classroom, laboratories are abysmally inadequate, unmaintained and lack requisite apparatus and equipment. The presence of chemicals and equipment for teaching and learning of chemistry practical may not be enough to bring about better performance of the students

without a competent chemistry teacher. According to Ali [14], these materials will hardly be helpful if the teacher does not use them effectively and efficiently.

Secondly, a research question was stated to determine the way Chemistry laboratory apparatus and chemicals stored in the schools under investigation. The findings of the study revealed that chemicals and apparatuses were organized or isolated, but the organization was not based on the scientific rules of chemicals and apparatus storage. This finding is similar to the idea or practice of the University of Utah's environmental Health and Safety department explained that alphabetization can be a helpful way to organize chemicals for easy access, but that it should not be used until after separating chemicals into categories.

The third research question for this study was to determine Chemistry teachers and students' extent of utilization chemistry laboratories for teaching and learning the subject chemistry in the schools. The findings of the study confirmed that the extent of these schools' utilization of the laboratory activities is either nil or once in a semester for grades 9 and 10. This finding is in line with Ochwada [40], who specified that learning is a complex task that comprises interaction of students' inspiration, physical facilities, teaching resources, skills of teaching and curriculum demands.

The fourth research questions were intended to examine the type of laboratory experimentation is commonly used in schools. The findings showed that there was no any laboratory-based teaching of the subject chemistry in 'Debremewii' secondary school and in 'Adet' secondary

school where teachers used the laboratory once in a semester demonstration was the commonly employed method. This finding is similar to the findings of the previous studies: Harty and Al-Faled [41]; Knox [42]; Cooke [43]; Carpenter [44]; who studied about the role and effect of demonstrations in both high school and college instruction and they were thought to be affective aids in increasing student's conceptual understanding in a summary of early opinion literature [45].

The fifth research objective was planned to evaluate the engagement of students', teachers' or both students' and teachers in the laboratory tasks. The finding of this study proved that students were not engaged actively in laboratory experimentation in both schools. Experiments are part and parcel of the current competence-based curriculum. This finding is in agreement with other previous findings for instance according to Omosewo [46] claimed that understanding of the science and technology procedures is achieved through laboratory tasks. Moreover, he stated that laboratory activities inspire active participation of learners and develops critical thinking. Laboratories provide concrete experiences to substantiate the theoretical aspect that has been taught. Similarly, Tilya [47] mentioned that, teaching by the use of laboratory helps the development of cognitive abilities. Additionally, students are expected to be actively involved in the learning process if they have to make ideas concrete and thoughts presented during the lesson and this is expected for any practical lesson to be significant [27].

The next research objective was intended to examine how Students' laboratory performance is assessed in relation to Bloom's taxonomy of learning domains (cognitive, affective,

or psychomotor) components. The findings clearly showed that in the schools under investigation students' laboratory performances were not assessed. The finding of the previous researches also showed that students' laboratory performance assessment was a challenge in most secondary and tertiary levels. The domains of learning as described by Bloom's Taxonomy are the cognitive, affective and psychomotor [48]. Relative to the laboratory performance assessment of students, the research finding is in agreement with that of Twoli [49] who stated that assessment is an important aspect of any educational programme. This assertion is supported by Ayot [50] and Breener [51] who both stressed that the techniques and frequency of assessment profoundly affect the content of the curriculum, how it is taught and ultimately performance. Performance tasks, in addition to assessing student abilities, offer students authentic practices through which understanding can be constructed and therefore work as instructional tools to enhance student learning [52].

Last research objectives were intended to identify the problems faced in using chemistry laboratories in the teaching and learning of chemistry in the schools. The finding revealed that, the chemistry teachers, department heads, vice directors sampled for this study agreed that the factors inhibiting effective utilization of chemistry laboratory include: inadequate availability of chemistry laboratory facilities, absence of well-trained laboratory assistant, lack of appropriate skills and training of chemistry teachers, and lack of important facilities including electricity and water to the laboratory rooms were some among the others. This finding is in line with the finding of Samwel

[53] who similarly recognized the above influences as challenges influencing actual utilization of chemistry laboratory for teaching chemistry.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Below are the main findings of this study based on the research questions.

- a) The study confirmed that chemicals and apparatuses in both ‘Adet’ and ‘Debremewii’ secondary schools’ chemistry laboratory were not adequately available.
- b) The findings of the study realized that chemicals and apparatuses were isolated separately but the organization was not based on the scientific rules of chemicals and apparatus storage.
- c) The study verified that both schools were not employing chemistry laboratory for teaching chemistry practically.
- d) The findings showed that ‘Adet’ secondary school teachers were used the laboratory once in a semester and in this particular case demonstration was the commonly employed method.
- e) The study verified that students were not engaged in laboratory activity in learning the subject chemistry in both secondary schools.
- f) The findings of the study showed that students’ laboratory performances were not assessed in both schools.
- g) The study confirmed that, inadequate availability of chemistry laboratory facilities, absence

of well-trained laboratory technician, lack of appropriate skills and training of chemistry teachers, and lack of electricity and water facilities to the laboratory rooms were identified challenges.

Conclusions

The enhancement of secondary school chemistry laboratory is a serious problem that needs to be addressed very recently. The current study investigated the practices, utilization and challenges of sampled secondary schools of Amhara region, Ethiopia. The finding of the study has provided the basis for the researcher to conclude that laboratory facilities are highly inadequate, falling short of a standard or norm for practical chemistry instruction. Therefore, in both schools' chemistry experiments were not being conducted. Hence, concerned stakeholders should give due attention and solve this serious problem.

Furthermore, the few chemicals and apparatuses available in the school were not organized using scientific ways of chemicals and apparatus storage. Additionally, both secondary schools were not using practical chemistry laboratory in teaching chemistry and however, 'Adet' secondary school used the laboratory once in a semester to demonstrate a few selected chemistry practical activities. On the other hand, students' laboratory performances were not assessed in both schools and availability of inadequate chemistry laboratory facilities, absence of well-trained laboratory technician, lack of appropriate skills and training of chemistry teachers, and lack of electricity and water facilities to the laboratory rooms were identified challenges in both schools.

Therefore, to attain the aim of chemistry education, all stakeholders should device workable strategies to ensure adequate provision and utilization of laboratory resources for effective chemistry instruction in both schools.

Recommendations

From the findings of this study, the following recommendations are made:

- 1) Laboratory facilities should be made available by school administrators and the government for meaningful teaching and learning in secondary schools.
- 2) Chemistry teachers should be involved in capacity building and refreshment retraining, workshops and seminars to help them acquire the skills and keep them up-to-date with the importance for effective teaching and learning of chemistry using laboratory.
- 3) The government, non-governmental organization, institutions working under education, and the community should also try to equip the school's chemistry laboratories adequately to encourage the teachers to conduct chemistry practical lessons.
- 4) Chemistry teachers should try to localize the concepts and use the school chemistry laboratory for chemistry instruction until other laboratory facilities are fulfilled.

ACKNOWLEDGEMENTS

We are immensely grateful to ‘Adet’ and ‘Debremewii’ higher secondary school leaders, teachers, laboratory technicians, and students who have participated in the study and enabled us in this great endeavor.

REFERENCES

1. Jin, J. (2015). Science & Technology and Modernization. In *Civilization and Modernization: Proceedings of the Russian–Chinese Conference 2012* (pp. 87-102).
2. Derkatch, m. (1991). UNESCO: Priorities in Science for the Benefit of Developing Countries. *World Affairs: The Journal of International Issues*, 2, 79-82.
3. Hunde, A. B., & Tegegne, K. M. (2010). Qualitative Exploration on the Application of Student-centered Learning in Mathematics and Natural Sciences: The case of Selected General Secondary Schools in Jimma, Ethiopia. *Ethiopian Journal of Education and Sciences*, 6(1).
4. Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science education*, 88(1), 28-54.
5. Osborne, J., & Dillon, J. (2010). Good practice in science teaching. Maiden-head; New York: Open University Press.
6. Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of ‘relevance’ in science education and its implications for the science curriculum. *Studies in Science Education*, 49(1), 1-34.
7. Takwate, K. T. (2018). Allocation, availability and maintenance of school facilities as correlate of academic performance of senior secondary school in Anambra State, Nigeria. *International Journal of Scientific and Research Publications*, 8(9), 42-81.
8. Pareek, R. B. (2019). An assessment of availability and utilization of laboratory facilities for teaching science at secondary level. *Science Education International*, 30(1).
9. Mwangi, A. W. (2013). *School-based factors influencing pupils’ academic performance in Kenya certificate of primary education in Tetu District, Nyeri County, Kenya* (Doctoral dissertation, University of Nairobi).
10. Masime, P., & Masime, P. (2016). *Effect Of Laboratory Resources Availability and Usability on Students’ achievement in Practical Chemistry in Sotik Sub-County, Kenya* (Doctoral Dissertation, University of Eldoret).
11. Bal-Taştan, S., Davoudi, S. M. M., Masalimova, A. R., Bersanov, A. S., Kurbanov, R. A., Boiarchuk, A. V., & Pavlushin, A. A. (2018). The impacts of teacher’s efficacy and motivation on student’s academic achievement in science education among secondary and high school

- students. *EURASIA Journal of Mathematics, Science and Technology Education*, 14(6), 2353-2366.
12. Mtsi, N., & Maphosa, C. (2016). Challenges encountered in the teaching and learning of the natural sciences in rural schools in South Africa. *Journal of Social Sciences*, 47(1), 58-67.
13. Nigussie, A., Mohammed, S., Yimam, E., Wolde, W., Akalu, N., Seid, A., ... & Mulaw, S. (2018). Commenting on Effective Laboratory Teaching in Selected Preparatory Schools, North Shewa Zone, Ethiopia. *Educational Research and Reviews*, 13(4), 543-550.
14. Ali, N., Ullah, S., Alam, A., & Rafique, J. (2014). 3D interactive virtual chemistry laboratory for simulation of high school experiments. *Proceedings of EURASIA GRAPHICS*, 1-6.
15. Layton, D. (1990). Student laboratory practice and the history and philosophy of science. In E. H Hegarty (Ed), *The student laboratory and the science curriculum*. London and New York: Routledge.
16. Education, F. D. R. E. (1994). Training Policy of Ethiopia. *Addis Ababa*.
17. Ethiopia's, A. S. P., & PIF, I. F. (2010). Federal Democratic Republic of Ethiopia Ministry of Agriculture and Rural Development.
18. Hastings, R. P., & Bham, M. S. (2003). The relationship between student behaviour patterns and teacher burnout. *School psychology international*, 24(1), 115-127.
19. Ndifon, R. A., Edu, G. O., Olofu, M. A., & Adie, J. A. (2021). The Role of Stakeholders in the Implementation of School Curriculum in Nigeria. *European Journal of Social Sciences*, 62(2), 20-31.
20. Otieno, O. H., & Deya, D. O. (2018). Contributions of Physical Facilities on Effective Management of Public Secondary Schools in Uriri Sub-County, Migori County, Kenya.
21. Onderi, H., & Malala, G. (2012). A review on extent of sustainability of educational projects: A case of strengthening of mathematics and science in secondary education (SMASSE) project in Kenya. *International Journal of Physical and Social Sciences*, 2(1), 123-144.
22. Creswell, J. W., & Zhang, W. (2009). The application of mixed methods designs to trauma research. *Journal of Traumatic Stress: Official publication of the international society for traumatic stress studies*, 22(6), 612-621.
23. Mugenda, O., & Mugenda, A. (2003). Research methods: Quantitative & Qualitative approaches. Nairobi: African Centre for Technology Studies press.
24. Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. (2003). Advanced mixed methods research designs. *Handbook of mixed methods in social and behavioral research*, 209(240), 209-240.
25. Kombo, D., K., and Tromp, D.A. 2006. Proposal and thesis writing; an introduction;2nd reprint; Pauline Publication Africa; Kenya. www.wagner.nyu.edu/.../whatisresearch.php Accessed 18/5/2011.

26. Jenkin, Dudek, G., M., Milios, E., & Wilkes, D. (1985). Robotic exploration as graph construction. *J. Comput.*, vol, 7(3).
27. Millar, R. (2004). The role of practical work in the teaching and learning of science. *Commissioned paper-Committee on High School Science Laboratories: Role and Vision. Washington DC: National Academy of Sciences*, 308.
28. Lewis, K. (2003). Measuring transactive memory systems in the field: scale development and validation. *Journal of applied psychology*, 88(4), 587.
29. Muchai, A. N., & Twoli, N. W. (2015). Effect of practical work in physics on the students' performance in physics. *Building Capacity Through Quality Teacher Education Nairobi, Kenya July 14-16, 2015*, 220.
30. Barrow, L. H. (2006). A brief history of inquiry: From Dewey to standards. *Journal of Science Teacher Education*, 17(3), 265-278.
31. Onipede, H. (2004). National Development Hinges on Quality Education. The Comet, January 2, pp: 21.
32. Ihuarulam.A.I (2008) Chemistry teachers understanding and implementation of the senior secondary chemistry curriculum. *Nigeriann journal of Science and Educztional Research* 4(1) 151 – 158.
33. Akpan W 2006. Between responsibility and rhetoric: Some consequences of CSR practice in Nigeria's oil province. *Development Southern Africa* 23(2): 223-240.
34. Nkwocha, L U. (1998). That state of resources for communicating STM in secondary schools in Niger State. A paper presented at the 39th Annual Conference of STAN, 65-69.
35. Anyadiegwu, C. O. (2018). Availability and Utilization of Laboratory Resources in Teaching and Learning Biology in Enugu North Local Government Area of Enugu State. Published Project Report Submitted to the Department of Science Education, Godfrey Okoye University.
36. Niyitanga, T., Bihoyiki, T., & Nkundabakura, P. (2021). Factors Affecting Use of Practical Work in Teaching and Learning Physics: Assessment of Six Secondary Schools in Kigali City, Rwanda. *African Journal of Educational Studies in Mathematics and Sciences*, 17(1), 61-77.
37. Muse, B. (2017). *School-based Factors Influencing Implementation of Chemistry Curriculum in Public Secondary Schools in Garissa Sub County, Kenya* (Doctoral dissertation, University of Nairobi).
38. Etiubon, R. E. (2018). The Role of School Personnel in Quality Provision and Safety Management of Science Laboratory Facilities. In Etudor, E.; Etor, C. R.; Egwuasi, P. I.; & Emediongokon, C. I. (Eds.) *A Festschrift in Honour of Prof. (Mrs.) Grace Koko Etuk. Academic Research Network International*.
39. Eze, E. C. (2001). African philosophy and the analytic tradition. *Philosophical Papers*, 30(3), 205-213.

40. Ochwada, Y. (2021). Influence Of School Environmental Factors on The Teaching-Learning Process In Public Primary Schools: A Case Of Bungoma County, Kenya (Doctoral Dissertation, University of Eldoret).
41. Harty H, Al-Faled N (1983) Saudi Arabian Students' chemistry achievement and science attitudes stemming from lecture demonstration and small group teaching methods. *J Res Scie Tech* 20:861.
42. Knox WW (1936) The demonstration method of teaching chemistry. *J Chem Educ* 13:166
43. Cooke RL (1938) Demonstration versus laboratory once again. *J Chem Educ* 15:592.
44. Carptenter WW (1936) A study of the comparison of different methods of laboratory practice on the basis of results obtained on the basis of results obtained on tests of certain classes in high- school chemistry. *J Chem Educ* 3.
45. McKee, E., Williamson, V. M., & Ruebush, L. E. (2007). Effects of a demonstration laboratory on student learning. *Journal of Science education and Technology*, 16(5), 395-400.
46. Omosewo, E. O (2006). Laboratory Teaching Method in Science based discipline. *African Journal of Educational studies*. 4 (2): 65-73. <https://files.eric.ed.gov/fulltext/EJ1207305.pdf>
47. Tilya, F. (2003). Teacher support for the use of MBL in activity-based physics teaching in Tanzania. *University of Twente*.
48. Dooley, K. E., Linder, J. R., & Dooley, L. M. (2005). Writing instructional objectives. In *Advanced methods in distance education: Applications and practices for educators, administrators and learners* (pp. 118-131). IGI Global.
49. Twoli, N. Maundu, J. Muindi, D. Kiio, M & Kithinji, C. (2007). Instructional methods in education: A course book for general teaching methods. Nairobi: Kenya Institute of Education.
50. Ayot, H. O. (1987). Instructional methods (general methods) Nairobi.
51. Brenner, L. A., Vanderploeg, R. D., & Terrio, H. (2009). Assessment and diagnosis of mild traumatic brain injury, posttraumatic stress disorder, and other polytrauma conditions: burden of adversity hypothesis. *Rehabilitation psychology*, 54(3), 239.
52. Ernst, J. V., Glennie, E., & Li, S. (2017). Performance-based task assessment of higher-order proficiencies in redesigned STEM high schools of higher-order proficiencies in redesigned STEM high schools. *Contemporary Issues in Education Research (CIER)*, 10(1), 13-32.
53. Samwel, K. (2016). *Assessment of school resources in public secondary schools in Bukoba municipality, Bukoba district-Tanzania* (Doctoral dissertation, Kampala International University, College of Education, Open and Distance Learning).

FEASIBILITY OF DOING INSIGHTFUL FINAL YEAR PROJECTS IN CHEMICAL SCIENCES AT HOME

Concepts, Themes, Outcomes, Challenges, Resources, Journals

K. Sivakumar

Department of Chemistry, Faculty of Science

Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya (Deemed to be University)

[SCSVMV University], Enathur, Kanchipuram – 631 561, Tamilnadu, India.

Email: chemshiva@gmail.com

ABSTRACT

Complete and partial restriction in the access to the laboratories in many countries has imposed a long-term lockdown to safeguard the citizens from the corona virus/omicron pandemic. Hence, e-teaching is in force effectively to teach theoretical as well as experimental courses. Unfortunately, undergraduate and postgraduate students of doing chemical sciences are missing their one-time opportunity for doing project during their course work. In this report, we discuss the *feasibility of doing final year projects in chemical sciences at home*. We suggest some themes, and concepts on which the students can take-up and carryout with the supervision of their professors. The resources and tools that is available online for executing the final year project is identified and explained. The practical approaches, directions for fruitful outcomes are discussed with the understanding on the limitations of such projects. This report would serve the chemical science students and teachers as one point reference material to identify a suitable theme for completing the final year project. [*African Journal of Chemical Education—AJCE 13(1), January 2023*]

INTRODUCTION

Purpose of Final Year Projects in a Chemical Science Course Curriculum

Purpose of final year projects in the curriculum of any chemical science program is to provide the students an opportunity to practice the theoretical knowledge that they have gained through core courses. Learning by doing is the ultimate objective of the final year projects. Students at the end of the course learn to define the problem for the projects, approach of investigation of the problem and methods to be adopted for investigating problem through the regular interaction with the teachers/supervisors. Final year project is a platform for the students to understand their laboratory skills and competence. Apart from the scientific objectives demonstrated above the final year projects help the students to develop interpersonal skills, problem solving skills and being creative in solving any problem in general.

The Pandemic Impact

Lockdown imposed throughout the world due to covid and omicron pandemic since December 2019 has become a great barrier for knowledge transfer process. Students are unable to access the laboratories for carrying out experiments, project work and research work till now. The situation has not developed instead the context has worsen than earlier. Covid cases and death due to pandemic are increasing day by day unexpectedly. Although the partial knowledge transfer

process is happening through online platforms, students are facing difficulties and losing their learning experience that they are supposed to gain through project work.

Identifying the feasibility of doing project at home using online resources is an essential task now. Hence, this article investigates the feasibilities of completing an insightful undergraduate and postgraduate final year project with the help of online resources. In this review, some of the concepts, themes, outcomes, challenges, resources, and journals useful for completing the final project are proposed.

A perfect literature review precisely narrates and communicates by connecting the chronological advancement with respect to the scientific fundamentals [1]. Writing literature review on a selected topic is one of the highly prioritized, feasible and meaningful ways of doing research at home. Writing a literature review on a specific theme involves certain set of process. The student has to select a topic for literature review, carryout extensive online search for identifying suitable articles, reading the collected reprints, developing the scheme of the review work, and scripting the review manuscript. Conducting a literature survey and scripting the findings based on the development in the field chronologically helps to understand the advancement stages that help to build our knowledge. In addition to that, literature survey and writing a review helps to narrow down the topic of further research or could be able to suggest specific research problems to be explored.

Although, carrying out a literature survey has become easier than earlier with the evolution of internet and ICT tools, writing an impressive literature review article is a time-consuming

complex process. Selecting a topic for literature survey is a great challenge for the beginners (students) and hence the meticulous guidance by the supervisor is required. Otherwise, the students would be wasting most of the time and get frustrated due to the lack of ability and confidence to decide. Students find difficult to understand the research papers. In general, students of graduate programs and even doctoral research scholars used to compose all the data, information and details obtained through Google search in a review report. And most of the literature review compilations by the students are lacking connectivity and continuity. Supervisors always identify the deviation of discussion / narration developed by the scholars/students in a literature review report. Research supervisors generally observe the lack of *connective description of scientific findings with chronological advancement* in the review reports drafted by the scholars and graduate students. But such defects can be rectified through the frequent short virtual/offline discussion and meticulous guidance by the supervisors for beginners. Attempting to write *narrative reviews* are suitable for graduate students rather than *systematic review* [2].

Themes: Generally, doctoral students would have many defined topics for writing a literature review. But, suggesting / finding a topic for writing a literature review for a graduate student, the supervisor has to do some preliminary searches. Usually, university professors used to suggest a topic for literature survey relevant to the supervisor's current research interests. Literature reviews based on (i) performance comparison of application materials/molecules, (ii) current / emerging areas, (iii)

discoveries and breakthrough advancements, (iv) scope for further advancements, are some of common themes.

Outcomes: The student gain (i) insights on the current status of the research theme discussed in the review article and, (ii) recommendations and suggestions for further research.

Challenges: A *systematic review* is focused on finding answer for a specific question and hence excludes holistic compilation of literature whereas the *narrative review* article is highly scattered in manner due the random selection of literature data.

Resources: Google Scholar [3], Web of Science [4], Scopus [5], SciFinder [6], PubMed [7], and Reaxys [8] are the major electronic resources for retrieving relevant literature data.

Journals: Nature Chemistry (*Nature*), Chemical Reviews (ACS), Chemical Society Reviews (RSC), Coordination Chemistry Reviews (*Elsevier*), Reviews and Advances in Chemistry (*Springer*), Comments on Inorganic Chemistry (*T&F*).

Concept: *Theoretical Chemistry; Predicting the molecular function*

Theoretical chemistry demonstrates the properties and structure of molecules. Theoretical chemistry is the branch of chemistry which develops theoretical generalizations that are part of the theoretical arsenal of modern chemistry: for example, the concepts of chemical bonding, chemical reaction, valence, the surface of potential energy, molecular orbitals, orbital interactions, and molecule activation. Computational chemistry, molecular modelling, molecular dynamics, molecular mechanics, mathematical chemistry, cheminformatics and theoretical chemical kinetics are some of

the main branches of theoretical chemistry. Understanding the molecular physics, atomic physics, and chemical physics are also related to theoretical chemistry discipline. In general, laboratory experiments and experimental chemistry research are the outcome of theoretical concepts. Experimental results are demonstrated using the theoretical principles and the theoretical chemistry insights evolves to set experimental hypothesis [9]. Hence, experimental research in chemical sciences and the theoretical chemistry insights are inseparable. However, deriving new concepts, principles, equations, theorems, tools, and resources for understanding the functions of atoms and molecules are the main purpose of theoretical chemical research.

Themes: Although, many non-experimental branches of research are possible in theoretical chemistry. Feasibility of doing undergraduate and postgraduate final year project in molecular mechanics, molecular dynamics, and cheminformatics is very less. But, learning the computational tools for molecular modelling, docking, molecular energy minimization, molecular energy estimation using the online serves, tools and visualization tools would be easy.

Outcomes: Students could realize the connection between chemistry, physics, and mathematics and computer science by taking up a project on theoretical chemistry. Students understand the importance of developing models based on logical theories to corroborate with the results obtained through experiments.

Challenges: Generally, theoretical chemistry research needs collaboration with physics, mathematics and computer science researchers. And, graduate students may not be interested in taking up topics on core theoretical chemistry themes.

Resources: The self-guided introduction on theoretical chemistry for College Students and non-experts developed by Jack Simons, Professor of Chemistry at the University of Utah would be good starting point for the beginners [10].

Journals: Nature Chemistry (*Nature*), J.of Chemical Theory and Computation (ACS), Computational and Theoretical Chemistry (*Elsevier*), Theoretical Chemistry Accounts(*Springer*), Int. J. of Quantum Chemistry (Wiley), J. of Computational Biophysics and Chemistry(*World Scientific*).

Concept: *Computational Chemistry; Insights on Molecules*

Computational chemistry is a branch of theoretical chemistry that computes the behaviour of molecules in various materials like nanoparticles, catalysts, adsorbents, surfactant, proteins, polymers, drugs etc., Generally, researchers understand the functioning of the molecules/atoms / sub atomic particles by imagination and speculate. The instrumental techniques like microscopic and spectroscopic results are indirect methods to understand the behaviour and functioning of molecules in materials. Such, behaviours could be made available for visualization through computational chemistry tools. Computational parameters like energy, thermodynamic data, HOMO-LUMO, electrostatic maps, electron density, steric effect, binding energy, complementarity scores, docking

scores are used as complimentary data for the experimental results. In some research investigations like drug discovery, pharmacophore synthesis design are finalized based on the computational and simulation results [11,12].

Themes: Computational chemistry themes could be broadly classified into two categories namely (i) structure of molecules, (ii) reactivity of molecules. Estimating the energy of a molecular structure is one of the key aspects of computational chemistry. Computing bond angles, dihedral angles, bond lengths and electrostatic potential maps. Optimization of structure by minimizing the energy of molecules, prediction of possible isomers and understanding the spatial arrangement of atoms are some of the specific feasible themes that could be useful for the graduate students. Hence, computational chemistry is highly useful in understanding the chemistry of materials without doing much wet lab investigations.

Outcomes: In general, computational chemistry yields molecular, atomic and sub atomic level insights. In addition to the results obtained, visualizing the trajectories computed provides clarity on the changes due to reaction / interactions. Students would be able to gain knowledge on the molecular dynamics during and after the reaction. Insights on molecular/atomic structure, enthalpy of reactions, different types of interactions, interactions beyond molecules, electrostatic interactions, binding energies, and thermodynamic parameters, and vibrational frequencies, mechanical and electrical properties of molecules of different application materials can be derived.

Challenges: Students find difficulties in learning the computational tools. However, students can familiarize and improve proficiency by self-learning by using online tutorials with the guidance of project supervisors.

Resources: www.vcclab.org, www.computationalscience.org/cccehttp, www.ccl.net, <https://chemcompute.org> – are few resources useful for the beginners.

Journals: J. of Chemical Information and Modelling (ACS), Applied Computational Chemistry (RSC), J. of Chemical Physics (AIP), J. of Computational Chemistry, (Wiley), J. of Molecular Structure, (Elsevier), J. of Computer-Aided Molecular Design, Structural Chemistry, J. of Molecular Modeling (Springer), Molecular Physics, Molecular Simulation (T & F).

Concept: *Molecular docking; Molecule-Molecule binding*

Molecular docking is an effective method to assess and interpret the binding of molecules on each other [13,14]. The crystallographic data (3D structural data) of molecules are used in docking software like Patchdock [15] and Autodock [16] for evaluating the binding ability of ligand on the target. Docking simulations yields different ligand-target complex with variable energies. The trajectory / conformation with lowest energy is identified as stable *ligand-target* complex. Molecular docking investigations with different ligands (drug) on a specific single target molecule would be useful in finalizing the most probable ligand with strong binding attributes. Such docking studies are helpful in finalizing the selection of ligand for further synthesis in the wet lab through experimental procedures. Docking investigations are useful to derive insights on, binding of drug molecules on

proteins, small molecules docking, supramolecular complex formation, and orientation preference of guest molecule into the host molecule, drug designing, and enzyme activation energy.

Themes: Binding site prediction, small molecule docking, molecular interactions, host-guest docking, reaction mechanism interpretation, lead optimization, predicting the energetically favourable orientation/conformation/binding, assessing the suitability of drug (ligand) molecule for the disease (target) molecule under investigation, protein-protein interaction.

Outcomes: Upon practicing molecular docking studies, students would get familiar about the docking and visualization tools. Students would be able to identify the binding sites in ligand and target, understand the atomic level interactions leading to the intermolecular forces, compare the binding strength of different drugs on the target, efficacy and toxicity of drugs.

Challenges: Beginners should familiarize the 3D structure generation tools and crystallographic data file handling before learning the docking technique. Understanding the 3D structure data takes much time for the undergraduate level students, however, it is possible to overcome by self-learning through online tutorials and with the help of project supervisors.

Resources: Click2Drug [17] is one of the comprehensive resource that consists of structural databases and relevant resources. Downloadable small molecule 3D structures can be obtained from, ACD (Available Chemical Directory) [18], CSD (Cambridge Structural Database) [19], MDDR (MDL Drug Data Report) [20], NCI (National Cancer Institute Database) [21].

Journals: J. of Chemical Information and Modelling (ACS), Applied Computational Chemistry (RSC), J. of Chemical Physics (AIP), J. of Computational Chemistry, (Wiley), J. of Molecular Structure, (Elsevier), J. of Computer-Aided Molecular Design, Structural Chemistry, J. of Molecular Modeling (Springer), Molecular Physics, Molecular Simulation (T & F).

Concept: Molecular Property Prediction;

Properties of molecules (drug) could be predicted using the molecular property predictor tools. Molecular attributes [22] like pKa, binding affinity, stability, solubility, weak interactions, electrostatic dynamics, H bonding, membrane permeability, transport, metabolic mechanism, pi electrons, sigma electrons, polarity, dipole moment, hetero atoms, aliphatic chains, aromatic cycles, rigid and rotatable bonds, receptor moieties, hetero cycles, rings, conjugation, accessible surface area, aliphatic rings, aromatic rings, hydrogen bond donor and acceptor, lipinski hydrogen bond donor, number of atoms, pKa, hetero cycles, molecular weight, topology, hydrophobicity, size, flexibility, rigidity, steric effect, molecular polar surface area, toxicology, efflux characteristics, Aqueous solubility calculation and electronic distribution could be calculated using the various molecular property tools. Drug-Target Binding Affinities (DTBA), Quantitative structure–activity relationship (QSAR) and quantitative structure–property relationships (QSPR), quantitative structure–chromatography relationships (QSCRs), quantitative structure–reactivity relationships (QSRRs), quantitative structure–toxicity relationships (QSTRs), quantitative structure–electrochemistry relationships (QSERs), quantitative structure–biodegradability relationships

(QSBRs), and absorption, distribution, metabolism, excretion, and toxicity (ADMET) studies are essential in drug design and development.

Themes: Molecular property prediction, QSAR, QSPR, drug-likeness, physiochemical properties prediction, drug-target binding affinities.

Outcomes: Students could easily familiarize a set of online molecular property predictor. Efficiency of similar drug compounds could be estimated using the molecular property predictor.

Limitations: Prediction results and interpretations would be an outcome of the chosen molecular descriptors and molecules. However, project supervisor's guidance is a vital role in identification of the problem for the study.

Resources: MolGpKa (<https://xundrug.cn/molgpka>), Virtual Computational Chemistry Laboratory (<http://www.vcclab.org/>), mcule (<https://mcule.com/apps/property-calculator/>), QSAR, drug design, molecular modelling, similarity searches. (<https://www.molinspiration.com/>), Drug Likeness prediction (<https://molsoft.com/mprop/>), chemspider (<https://www.chemspider.com/ACDLabs.aspx>), chemical interference with a biological pathway (<http://www.thegreentest.com/>), ToxiM (<http://metagenomics.iiserb.ac.in/ToxiM/>), ADMET [23] analysis; BioTransformer (<https://bitbucket.org/djoumbou/biotransformerjar/>), SwissADME (<http://www.swissadme.ch/>), ADMETlab (<https://admetmesh.scbdd.com/>), vNN-ADMET (<https://vnnadmet.bhsai.org/vnnadmet/login.xhtml>).

Journals: Scientific Reports (nature), Journal of Chemical Information and Modeling (ACS), QSAR & Combinatorial Science, Molecular Informatics (Wiley), SAR and QSAR in Environmental Research, Expert Opinion on Drug Discovery(T & F), Molecules (mdpi).Journal of Cheminformatics (BMC),

Concept: *In silico analysisof proteins; Predicting protein properties*

The UniProt (www.uniprot.org) database consists of around 6 million protein sequences. The protein data available in UniProt database are highly curated by the experts. Protein sequence data can be easily downloaded from the database through a search interface (<https://www.uniprot.org/uniprot/?query=reviewed:yes>) by typing the protein of interest. The protein sequence retrieval process is similar to the google search. The physico-chemical and structural properties of the retrieved protein sequences could be analysed using various protein sequence analysis tools and servers. Most of the sequenced proteins lack a descriptive, documented physico-chemical and biochemical characterization. Because, experimental methods are trial and error-based and time consuming. Hence, computational approaches become especially significant. The tools and prediction servers available on the Internet, predict the various physico-chemical and biochemical properties and parameters required for designing the experiments for further protein analysis, thereby, minimizing the number of experimental trials and reduces the cost of experimental analysis. The whole process takes very little time and it provides not only faster but also accurate results.

Themes: physico-chemical parameters of protein sequences such as theoretical isoelectric point, molecular weight, total number of positive and negative residues, extinction coefficient, half-life, instability index, aliphatic index and grand average hydrophathy could be computed using the Expasy's ProtParam (<http://us.expasy.org/tools/protparam.html>) prediction server. The tools SOPM, SOPMA and SSCP servers could be used for predicting the secondary structure of proteins [24].

Outcomes: Students could familiarize the various bioinformatics tools and understand the role of molecular moieties / scaffold (functional groups) responsible for the characteristics of proteins.

Challenges: Understanding the protein sequence formats existing in the databases would be difficult for the beginners. Fixing the set of physico-chemical parameters for analysis and familiarizing the relevant tool would be difficult where project supervisor's guidance is mandatory. It could also be achieved through collaborating with researchers with suitable expertise.

Resources: The following list of online bioinformatics servers could be useful in predicting the physico-chemical properties of proteins (sequences). Tools for Sequence Analysis (<http://www.expasy.ch/tools/>), Compute pI/Mw tool (http://au.expasy.org/tools/pi_tool.html), ExPASy's ProtParam (<http://us.expasy.org/tools/protparam.html>), NetOGlyc (<http://www.cbs.dtu.dk/services/NetOGlyc/>), NetNGlyc (<http://www.cbs.dtu.dk/services/NetNGlyc/>), NetPhos(<http://www.cbs.dtu.dk/services/NetPhos/>), SignalP (<http://www.cbs.dtu.dk/services/SignalP/>),

SAPS (<http://www.isrec.isb-sib.ch/software/SAPS-form.html>),

SOPM (http://npsa-pbil.ibcp.fr/cgi-bin/npsa_automat.pl?page=npsa_sopm.html),

SOSUI (http://sosui.proteome.bio.tuat.ac.jp/cgi-bin/adv_sosui.cgi),

TMHMM (<http://www.cbs.dtu.dk/services/TMHMM-2.0/>).

Journals: Briefings in Bioinformatics (Oxford University Press), Computational Biology and Chemistry (Elsevier), Bioinformatics (BMC), Advances in Bioinformatics (hindawi), Austin Journal of Proteomics, Bioinformatics & Genomics (Austin Publishing Group), Bioinformation (Biomedical Informatics).

Concept: Homology modelling; shaping the structure of protein

Proteins function depends on its shape (i.e., three dimensional structure) and the shape of a protein depends on its primary structure (i.e., sequence of amino acids). Hence, the knowledge of proteins shape (3D structure) plays a vital role in understanding the functions of proteins. 3D structure of proteins provides a solid framework for planning experiments and for the interpretation of their results. Experimental structure determination methods are highly expensive, time consuming due to elaborate technical procedures. And the experimental methods are not always successful because many proteins fail to crystallize and cannot be dissolved in large quantities. Till data more than 10 million protein sequences are deposited by the scientists of different countries in the databases like Uniprot, International Protein Sequence Database, and Protein Research Foundation. But, the 3D structure of just 1.85 Lac proteins is estimated through experimental methods and deposited in

Protein Data Bank (<https://www.rcsb.org/>). It is obvious now that 3D structure of more than 10 million protein sequences is not estimated experimentally. Hence, computational method is preferred to build (model) the protein three-dimensional structure. Well established procedures with the help of online servers and tools highly quality 3D structure (of proteins) can be modelled from the primary structure (amino acid sequence) of a protein. Homology modelling is one of the simplest and fastest ways of constructing the 3D structure of a protein.

The major sequential steps in homology modelling are, (i) searching known 3D structures that are related to the target sequence, (ii) selecting the suitable 3D structures that will be used as templates, (iii) aligning the target sequence with the template structure, (iv) building the model for target sequence based on the alignment with the template, (v) evaluating the built model with the help of various tools. Alignment and model building is repeated until a quality 3D structure is achieved.

Themes: Homology modelling of protein [25, 26].

Outcomes: Students could familiarize the tools useful for homology modelling of proteins.

Challenges: Familiarizing the homology modelling tools and servers would be difficult task for the beginners. However, learning through online video tutorials would be helpful.

Resources: Protein similarity (3D structure) search tool; Blastp (<https://blast.ncbi.nlm.nih.gov/Blast.cgi>), 3D structure modeling servers; swissmodel (<https://swissmodel.expasy.org/>), ESyPred3D (<https://www.unamur.be/sciences/biologie/urbm/bioinfo/esypred/>), Protein 3D structure quality predictors; ProQ (<https://proq.bioinfo.se/ProQ/ProQ.html>), Ramachandran Plot Server (<https://zlab.umassmed.edu/bu/rama/>). The databases, ModBase (<http://alto.compbio.ucsf.edu/modbase-cgi/index.cgi>) and 3DCrunch (http://www.expasy.org/swissmod/SM_3DCrunch.html) consist of protein structures obtained by homology modeling.

Journals: Journal, Briefings in Bioinformatics (Oxford University Press), Computational Biology and Chemistry, Computational and Structural Biotechnology (Elsevier), Bioinformatics (BMC), Advances in Bioinformatics (hindawi), Austin Journal of Proteomics, Bioinformatics & Genomics (Austin Publishing Group), Bioinformation (Biomedical Informatics), Journal of Biomolecular Structure and Dynamics (T & F).

CONCLUDING REMARKS, SUGGESTIONS AND RECOMMENDATIONS

Usually, students think about the selection of research problem for project work in the final semester. Considering the continuing pandemic situation since 2019, final year project work should be initiated in the lower semester itself. Various themes suggested in this report relevant to the

chemical science concepts such as literature review, theoretical chemistry, computational chemistry, molecular docking, molecular property prediction, in silico analysis of protein sequences, and homology modelling would be useful for carrying the project work at home using online tools.

However, the meticulous supervision through online teaching platform is required to make it as an insightful one. Learning the tools related to various themes (search engines, docking, online servers, etc.,) would be definitely a challenging aspect to the students. But project supervisors can suggest suitable online tutorials (preferably video) to learn the tools quickly. The relevant resources and journals suggested for the various concepts and themes would be the additional reference.

REFERENCES

1. Elsa Alvaro, David A. Zwicky, Improving the Quality of Literature Reviews in Chemistry: Tools and Techniques, ACS Chem. Health Saf. 2021, 28, 5, 303–310.
2. Chemistry: Systematic Reviews, <https://guides.library.unr.edu/c.php?g=51139&p=7853773> (12/01/2022).
3. Google Scholar, <https://scholar.google.com/> (12/01/2022).
4. Web of Science, <https://clarivate.com/webofsciencegroup/solutions/web-of-science/> (12/01/2022).
5. Scopus, <https://www.scopus.com> (12/01/2022).
6. SciFinder, <https://scifinder.cas.org> (12/01/2022).
7. PubMed, <https://pubmed.ncbi.nlm.nih.gov/> (12/01/2022).
8. Reaxys, <https://www.reaxys.com> (12/01/2022).
9. Theoretical chemistry, https://en.wikipedia.org/wiki/Theoretical_chemistry (12/01/2022).
10. Web Page of Jack Simons, <http://simons.hec.utah.edu/> (12/01/2022).
11. Computational chemistry, https://en.wikipedia.org/wiki/Computational_chemistry (12/01/2022).
12. Nature Portfolio - Computational chemistry, <https://www.nature.com/subjects/computational-chemistry> (12/01/2022).

13. Garrett M Morris, Marguerita Lim-Wilby, Molecular docking, *Methods Mol. Biol.* 443 (2008) 365-382
14. Morris G.M., Lim-Wilby M. Molecular Docking. In: Kukol A. (eds) *Molecular Modeling of Proteins. Methods Molecular Biology*, (2008) vol 443. Humana Press.
15. Schneidman-Duhovny D, Inbar Y, Nussinov R, Wolfson HJ. PatchDock and SymmDock: servers for rigid and symmetric docking. (2005) *Nucl. Acids. Res.* 33, W363-367.
16. Jerome Eberhardt, Diogo Santos-Martins, Andreas F. Tillack, and Stefano Forli, AutoDock Vina 1.2.0: New Docking Methods, Expanded Force Field, and Python Bindings, *J. Chem. Inf. Model.* (2021), 61, 8, 3891–3898
17. click2drug, <https://click2drug.org/index.php#Databases> (12/01/2022).
18. https://blogs.rsc.org/chemical-database-service/2013/10/31/available-chemicals-directory/?doing_wp_cron=1641881542.6383121013641357421875 (12/01/2022).
19. <https://www.ccdc.cam.ac.uk/solutions/csd-core/components/csd/> (12/01/2022).
20. <http://www.akosgmbh.de/accelrys/databases/mddr.htm> (12/01/2022).
21. <https://www.cancer.gov/research/resources> (12/01/2022).
22. Jie Shen, Christos A.Nicolaou, Molecular property prediction: recent trends in the era of artificial intelligence, *Drug Discovery Today: Technologies*, (2019); <https://doi.org/10.1016/j.ddtec.2020.11.009>.
23. Ying Han, Jingpu Zhang, Chang Qin Hu, Xia Zhang, Bufang Ma, Peipei Zhang, In silico ADME and Toxicity Prediction of Ceftazidime and Its Impurities, *Front. Pharmacol.* (2019).
24. K. Sivakumar, S. Balaji, and Gangaradhakrishnan, "In Silico Characterization of Antifreeze Proteins Using Computational Tools and Servers", *Journal of Chemical Sciences*, 119 (5), (2007), 571-579.
25. Tareq Hameduh, Yazan Haddad, Vojtech Adam, Zbynek Heger, Homology modeling in the time of collective and artificial intelligence, *Computational and Structural Biotechnology Journal*, (2020) 18, 3494-3506
26. K. Sivakumar, S. Balaji, and Gangaradhakrishnan, Biocomputational analysis and characterization of some antifreeze proteins, *Journal of Theoretical and Computational Chemistry*, 6 (1), (2007), 127-140.

PERSPECTIVES ON GENERAL ASPECTS OF POLLUTION TOXICOLOGY

B.H.S. Thimmappa

Netra Jyothi Institute of Allied Health Sciences, Efkey Business Center, N.H.- 66,

Opposite ABCO Steels Ltd. Ambalpadu, Udupi-576103

Email: thimmappabhs@gmail.com

ABSTRACT

The advances in the study of adverse effects of particular chemicals on living systems allowed the prediction of the risks associated with it. The geographical environment involving industrialization, urbanization, and globalization has created an altered ecology that severely affected organisms. Toxic chemicals are also finding their way into our food chain, and the people develop bronchial problems and breathing difficulties. An understanding of the polluted environment helps the governments to determine, regulate and enforce environmental pollution control measures, such as legislation, governing the massive use of pesticides, or large-scale discharging of highly toxic industrial effluents that are central to conservation. If the human impact continues to transform the ecosystems because of the growing population and waste disposal, nature cannot bear the damage. The knowledge about environmental toxicology informs us about the risks, to promote higher levels of human intellect and attitudinal development, which will help ensure the future survival of the planet. Environmental education, adoption of the standardized environmental management systems, production of less toxic materials, sustainable management of resources, environmental auditing, and developing an eco-friendly technological innovation goes a long way in environmental protection. Novel waste treatment methods must be devised, and non-conventional power sources such as solar, wind, and biogas plants must be developed on a large scale to control the pollution and make the earth more habitable, peaceful, and safe for all creatures to live and thrive on. [*African Journal of Chemical Education—AJCE 13(1), January 2023*]

INTRODUCTION

Many different types of harmful materials are released into the atmosphere due to different sorts of human activities on micro- and macroscales in the rapidly urbanizing planet. Farmers spray pesticides on the crops, and some enter the soil, streams, rivers, and oceans. Harmful waste chemicals from industrial processes are discharged into rivers. Smoke and gases release from factories, power stations, and vehicles continuously spread in the air, causing severe air pollution. Chemicals from soaps and detergents and other household cleaning products finally enter the water system. Mining waste and rubbish are often dumped on the ground, contaminating the soil. Industrial operations produce wastes that pollute the air and groundwater. These different pollution types pose a threat to animal and plant life on the planet [Fig.1]

Global demand for certain plantation products such as coffee beans or cocoa can impact the ecology because of illegal plantations across protected areas of some countries, affecting the local animal population. Burning large amounts of impure coal in inefficient ways contribute to excess and maximize harm. Forest fires, accidental fire in buildings, mass cremation in natural disasters like a devastating massive earthquake, adulterated diesel-burning in vehicles, use of older vehicles, agricultural crop burning, and domestic cooking stoves also contribute to the air pollution problem and unpredictable climate change [1-4]. Construction of hydroelectric powerhouses, illegal sand mining, and deforestation

contribute to declining groundwater resources and polluted water bodies, disturbing the socio-economic fabric of the society. Even adventure sports events like off-roading rallies using all-terrain vehicles lead to soil erosion, noise, and air pollution, causing damage to the environment. The introduction of seaplane services in several coastal areas to encourage sea tourism will adversely impact the local fishing communities' livelihoods and marine ecology. Such operations will displace fish populations and migratory birds, degrade the environment by spillage of fuel, and result in higher carbon emission and noise pollution.

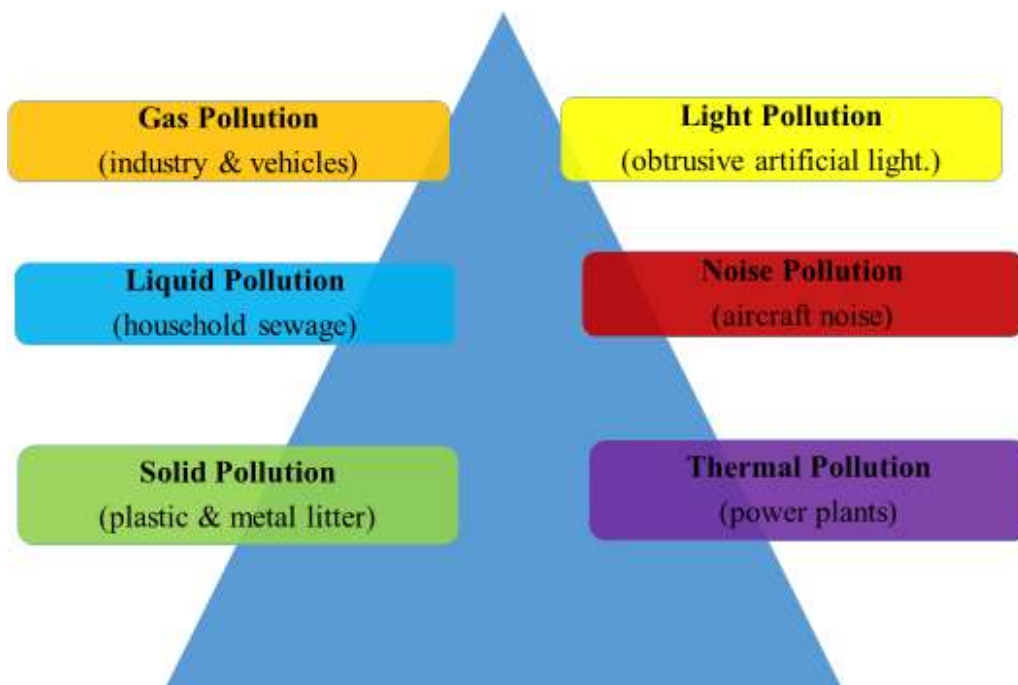


Fig. 1. Samples of selected different types of pollution in the troposphere, which poses potential health risks.

Thin-film technologies and microelectromechanical systems (MEMS) enable the integration of multifunctional sensor arrays (motion/sound/light/temperature/humidity) for home use [5]. There is an explosion in connecting devices such as personal computers, smartphones, tablets, internet of things, smart televisions, and wearables. Electronic waste (e-waste) generated worldwide from home appliances, computers, and smartphones is a growing concern over the next decade [6-7]. It contains hazardous substances such as mercury, sulfur, cadmium, lead, beryllium oxide, and hexavalent chromium, which has a severe environmental impact [8]. Biomedical waste, generated from biological and medical sources and activities, could potentially lead to the spread of infectious diseases.

When microorganisms such as virus and bacteria enter the human body produces toxins and affect the immune mechanism, leading to muscle and joint pains and fever. The noise pollution adversely affects the lives of millions of people worldwide, as there are direct links between unwanted sound and health. The sources include transportation systems, construction of buildings, industrial noise, public address systems, boilers, generators, and vacuum cleaners. The transport noise (road, air & rail traffic), occupational noise (high-tech machines, tractor, power-drill), and neighborhood noise (loudspeakers, television & radio sets, generators) are the three major categories of noise.

Radioactive waste and pollution increase the risk of damage to DNA, cells, and tissues. Climate change poses an existential threat to the species on the planet, and it is an

issue that is very important for the future of humankind. We have to maintain the global temperature within the 2o C threshold to avoid the problematic consequences of climate change. The primary human activities - deforestation, water and energy use, industrial and agricultural practices, and urban sprawl - contribute significantly to climate change [9]. These human activities have led to enhanced concentrations of greenhouse gases such as carbon dioxide, chlorofluorocarbons, methane, nitrous oxide, water vapor, and ozone in the atmosphere. These molecules absorb different wavelengths in the infrared region, causing the atmosphere to become warm (greenhouse effect), and this effective barrier prevents some heat from escaping the earth's surface. When released into the atmosphere, the CFCs are carried into the stratosphere, where they can absorb a significant amount of high energy ultraviolet light, forming chlorine radicals. These reactive radicals can catalyze the destruction of the ozone layer. The Montreal protocol called for reductions in the production and use of CFCs. The pollutants which enter the atmosphere directly from their sources are called primary pollutants [dust, soot (elemental carbon), nitric oxide, sulfur dioxide]. In contrast, those formed by the reaction of a primary pollutant in the environment under the influence of sunlight are called secondary pollutants (ozone, hydrogen peroxide, aldehydes). These two types of pollutants, along with dust, soot, and droplets of water form smog.

It is important to note that nature also pollutes the air on a large scale with volcanic ash, sulfur oxides, hydrogen chloride, pollen, methane gas, and odorous organic compounds from coniferous forests, dioxin emissions from forest fires. The excessive obstructive artificial skylight, particularly in highly industrialized and densely populated urban areas, cause light pollution. The streetlights and other human-made sources in the night have a disruptive effect on natural cycles and inhibit the observation of stars and planets. Public lighting is a significant source of greenhouse gas emissions. Another type of pollution called ‘thermal pollution’ causes damage to the environment from the waste heat of industrial processes. Water discharged from power stations is an example source of heat pollution.

Other sources of thermal pollution include nuclear power plants, hydroelectric power generation, and domestic sewage disposal. Particulate pollutants such as fly ash, silica, and dust released from volcanoes, fossil fuel burning, mining, and forest fires. The extent of such pollution and its effect depends on their size range, concentration, chemical nature, rate of settling, a period of exposure, and individual health. There are two sources of water pollution; point sources of constant volume and definite composition such as industrial wastewaters and diffused sources of unknown volume and composition such as agricultural and street run-off. Sludge from the sewage plants contains harmful toxic chemicals that affect the fertility of the soil. Accidental pollution, such as the recent massive

earthquake in Nepal (April 2015), has taken nearly 8,000 lives and does not provide enough time for humans and animals to escape.

Household air pollution (HAP) from fuels (charcoal, wood, kerosene) burnt at home for cooking, lighting, and heating purposes generate high concentrations of smoke particles. Even cigarette smoke causes much-localized air pollution and can lead to different kinds of health problems. Lung cancer incidence is nearly 20 times higher in smokers than in non-smokers. Many organic products may contaminate air, water, soil, and persistent organic pollutants (POPs) include dioxins generated from municipal or biomedical incinerators and polychlorinated biphenyls (PCBs) and organochlorine pesticides manufactured from chemical industries. These substances, because of their low solubility and high stability, persist in the environment and enter the food chain as pollutants to cause health risks. Freshwater pollution can occur by chemical effluents from industries, and marine pollution takes place by oil spills from tankers. When released into the environment, the vast quantities of organic solvents used in chemical manufacturing, industrial cleaning, textile dyeing, and food processing operations, lead to groundwater contamination and the buildup of GHGs. Thus, there are different categories of the introduction of harmful substances into the environment. Massive industrialization and urbanization and balancing economic development with environmental quality is a real challenge.

POLLUTION HAZARDS AND PUBLIC HEALTH ISSUES

The environment is a complex and dynamic system with interconnected life forms. The primary characteristics of the environment have been changing due to the removal of essential components like dioxygen and the addition of undesired components such as carbon, sulfur, and nitrogen dioxides. The effects of pollution can be gradual or dramatic, small-scale, or global.

Pollution hazards include injury or poisoning of animals, reduction of oxygen supply in contaminated water, destruction of food sources or vegetation cover, acid rain, and climate change. The photochemical smog produced mainly by the action of sunlight on auto-exhaust gases creates an unpleasant condition of pollution in specific urban environments. The eye irritants that cause tears, lachrymators, are oxidation products (peroxyacetyl nitrates) of primary pollutants.

The earlier Los Angeles and the more recent Beijing smog in 2014 created a piece of worldwide news, and these incidents indicate an early warning to take immediate corrective measures. One of the effects of thermal pollution of lakes is the decreased solubility of oxygen in water with an increase in temperature, and warm water tends to remain on top of cold water as it is less dense. This effect further impedes the oxygen dissolution in water, and fishes may die, and respiration of other aquatic life will be affected under these conditions. Water quality will be affected by the accumulation of organic materials such as sewage disposal, industrial wastes, and effluents in water. Water pollution is also caused by different types of microorganisms, including pathogens and chemical contaminants such as fluoride, chloride, and arsenic.

Aerobic bacteria consume dissolved oxygen to oxidize organic materials, leading to the depletion of oxygen in the water, and such poor-quality water is detrimental to animal life due to less than usual amount of dissolved oxygen. The ailments associated with water consumption with high fluoride concentration include dental and skeletal fluorosis, and it is crucial to overcome the impact of fluoride on water-table in the affected areas. Household air pollution exposure can cause reduced immune function, increasing the risk of bacterial pneumonia. When hydrocarbons and nitrogen oxides, released by automobiles, react with sunlight to produce ozone. The causes of a diminished population of some varieties of sparrow include pollution, pesticides, habitat destruction, lack of food, and signals from cell towers. The decline in honeybee population threatens crops like almonds and apples that depend on insects for pollination.

Noise has been considered as one of the dimensions of pollution that causes environmental degradation and health hazards. The loudest sound (≥ 130 decibels) causes pain to the human ear and listening to loud music for long can damage our hearing. The noise-induced hearing loss (NIHL) is common among the factory workers in the textile, automobile, fertilizers, and chemical industries. Other effects include headache, mental tension, blood pressure, heart diseases, and stomach trouble. Low-frequency noise at night can disturb the sleep of senior citizens and patients, causing adverse health effects. High-intensity noise is one of the major factors for chronic mental exhaustion. Beyond maximum recommended noise dose exposure levels, environmental noise causes widespread

damage to the human mind and body. Pollution in the troposphere can have adverse effects from burning eyes and cough to the destruction of vegetation and ancient monuments.

The current ozone concentrations in some urban areas are good enough to cause health hazards in children, pregnant women, people with respiratory disorders, and veterans with decreased respiratory capabilities. The road salt (sodium chloride) is used during winter in some parts of the globe, and this helps to lower the freezing point of ice and snow, facilitating their removal from roads. However, the dissolved salt runs off into adjacent streams, increasing their chloride ion concentration, and this water is not potable for humans and is toxic to some aquatic life. Some other effects of pollution are acid rain, the greenhouse effect, and the creation of an ozone hole allowing ultraviolet radiation that offers more exciting challenges.

Sulfur dioxide is produced by burning coal containing sulfur, and it is a major contributor to acid rain and industrial smog. It is released during the process of extraction of the free metals from their sulfides. This gas is corrosive and damages plants, structural materials, and causes throat and lung irritation. When it combines with moisture in the air, it forms sulfuric acid, the main cause of acid rain. The water in some lakes, streams, and ponds around the world are highly acidic and unfit for fishes, shrimp, and other aquatic organisms to live. The plant leaves suffer skeletal damage, and as a result, photosynthesis is affected. An aerosol of sulfuric acid, when inhaled, gets trapped in the lung, and cause severe damage. Aerosol particles in the atmosphere cause light scattering and haze in the atmosphere can lead to limited visibility in the area, raising the number of accidents. The

stratospheric ozone layer prevents ultraviolet radiation from reaching the earth's surface by undergoing a photodissociation reaction. This reaction is essential for the protection of people and plants on the earth's surface because the harmful UV radiation that reaches the earth's surface by ozone depletion can cause DNA-damage, skin cancer in humans, and damage to living plants.

Global warming, temperature increase due to the greenhouse effect, will cause more of the polar ice caps to melt, increasing the sea level and flooding coastal areas. Recent studies indicate a sudden dramatic change in the Antarctic Peninsula glaciers, and much of the ice streams are particularly sensitive to any changes in the ocean water temperature. Significant changes in atmospheric currents and weather patterns could affect agricultural productivity. Light pollution by misdirected or obtrusive artificial light in the outdoor environment causes energy waste, affects animals, human health, and psychology (impaired thinking and depression), and disrupts ecosystems. The light confuses and interferes with the migration of birds, and millions of birds die each year from collisions with tall towers and multistoried buildings with bright lights. Light clutter may create confusion, distract from obstacles, and potentially cause accidents. Oxygen becomes less soluble as the water temperature rises, and warm water rises to the surface of rivers as it is less dense.

This feature acts as an insulating blanket that prevents absorption and penetration of oxygen into inner layers of water, affecting the population of many marine species. Particulates scatter light and reduce visibility, causes allergic reactions, irritation and respiratory disorders, and silicosis. Polychlorinated biphenyls and the pesticide dichlorodiphenyltrichloroethane (DDT) are nonpolar.

Moreover, they are stored in the body of fish and certain animals. Suspended solid particulates aggravate bronchitis and asthma, and damages lung tissues. It is also important to note that certain diseases like cancer or byssinosis may strike 5-10 years after exposure, and some diseases occur in specific human population groups. Environmental toxins such as aluminum, lead, mercury, cadmium, and dioxins may contribute to Alzheimer's disease, respiratory ailments, skin diseases, and cancer.

Further investigation of population studies is required to establish a link between the amount of these toxins and the prevalence of particular diseases. The scale of biodiversity loss has increased as human activities, and a consequent change in the environment led to major extinction events. Air pollutants discolor historic buildings, marble structures, statues, and other monuments of cultural significance. The devastating earthquake and tsunami can cause partial damage or total collapse of buildings, contributing to environmental changes. The overall impact of pollutants and environmental chemistry depends on the pollution level, exposure to sunlight, nature of pollutants, and altitude.

CONTROL OF POLLUTION TOWARDS A SOLUTION

It is essential to regulate principal toxic pollutants like carbon monoxide, sulfur dioxide, nitrogen oxides, lead, mercury, and particulate matter (PM) to reduce local and global pollution levels and the adverse effects of atmospheric pollutants on human health and the environment [10].

It is important to note that many of the environmental issues are global as reflected in several international level conferences and meetings in the last two decades, and resources are limited and environmental challenges are huge [11]. We need to take certain immediate corrective measures such as a self-imposed code of conduct, instituting industry norms, imposing trade restrictions, and government policy and legislation to reduce harmful environmental impacts [Fig. 2]. It is essential to provide environmental education to realize the importance of environmental protection and develop the proper mindset of a progressive planet. Further focus on new domain expertise to address emerging environmental issues worldwide will pay rich dividends. It is important to stimulate and instill the passion of environment conservation amongst the local people and initiate movement towards sustainable development in harmony with nature to fulfill the greater cause of a healthy society.

Creating awareness about the harmful effects of pollution, using public transport vehicles, organic farming practices, controlling polluting activities, and adopting less-polluting lifestyles go a long way in reducing pollution, a pressing environmental issue. Organic farming methods to produce agricultural commodities help conserve soil and water quality and reduces pollution to a certain extent, in addition to personal health benefits. Agricultural model based on organic farming, irrigation projects, spraying herbal pesticides, timely water, and electricity supply can enhance farm productivity. Regular servicing and tuning of automobiles, planting bushes and trees, designing buildings with noise absorbing materials, and personal protective equipment can effectively reduce

noise pollution. Other measures to tackle the problem of noise pollution include the use of limited hour horns or no horns, increasing no vehicle entry zones, and banning use of loudspeakers in public functions, festivals, or cultural programs. Thus, noise pollution reduction measures include control of noise intensity at the source, noise absorption measures between the source and the recipient, and use of personal protective devices.

The cumulative effect of many corrective and preventive measures such as environmental education in the curriculum, political will and policy decisions, planned urbanization, land use, and mobility planning, reliable and efficient public transport systems, reducing the number of vehicles, adopting a variety of energy conservation measures, and use of lead-free and quality petrol will have an overall global impact. Other measures such as the use of natural dyes to color leather or textile, biodiversity conservation, use of CNG in vehicles, reducing the number of new vehicle registrations, and increasing green cover will enhance the local ecosystem to a large extent. To combat the problem of stratospheric ozone depletion, more than 150 countries have signed the protocol to ban ozone-depleting compounds such as chlorofluorocarbons (CFCs), halons, and methyl bromide. The recent results indicate that the levels of ozone-depleting chemicals are declining and will reach the pre-1980 levels by 2050. We have to control carbon dioxide emissions throughout the world to reduce global warming (1.5 to 4.5 oC) and ocean acidification. There is uncertainty in the temperature changes due to global warming because of complex parameters - warming due to human activities versus part of a natural cycle, the response of the earth's climate to the warming, and the extent of

GHGs in the coming decades. Trends in polluting gas emissions vary widely among different countries, and local control of such emissions, including the use of improved emissions- control technology and policy decisions, will result in significant reductions of adverse effects.

Use of alternative sources (CNG, methanol) in place of fossil fuels (natural gas, gasoline, coal, oil, and kerosene), planting more trees, improved combustion technologies, and improvements in emission control systems help achieve satisfactory levels of air pollutants. The use of catalytic converters in motorized vehicles to help convert the nitrogen oxide gases back to nitrogen and oxygen and also help in the complete oxidation of unburned hydrocarbons. Now, most of the sulfur dioxide is trapped and used in the manufacture of sulfuric acid to limit the amount of gas that escapes into the atmosphere.

The reverse osmosis (RO) method using a membrane (cellulose acetate) can be used to construct large scale plants to purify drinking water, and a portable RO unit designed for individual use provides the freshwater in our daily use. Use of energy-efficient lighting sources and motion-sensing lights, turning lights off when not required, and lighting legislation are some of the measures required to reduce severe photo pollution problems [12, 13]. A large-scale light-emitting diode (LED) bulb adoption will significantly bring down the global electricity bill as it uses less electricity. The thermal pollution problem due to industrial effluents can be tackled by installing cooling towers, which cool water before it comes out of the plant.

Cooling ponds and artificial lakes also offer other ways of fighting thermal pollution.

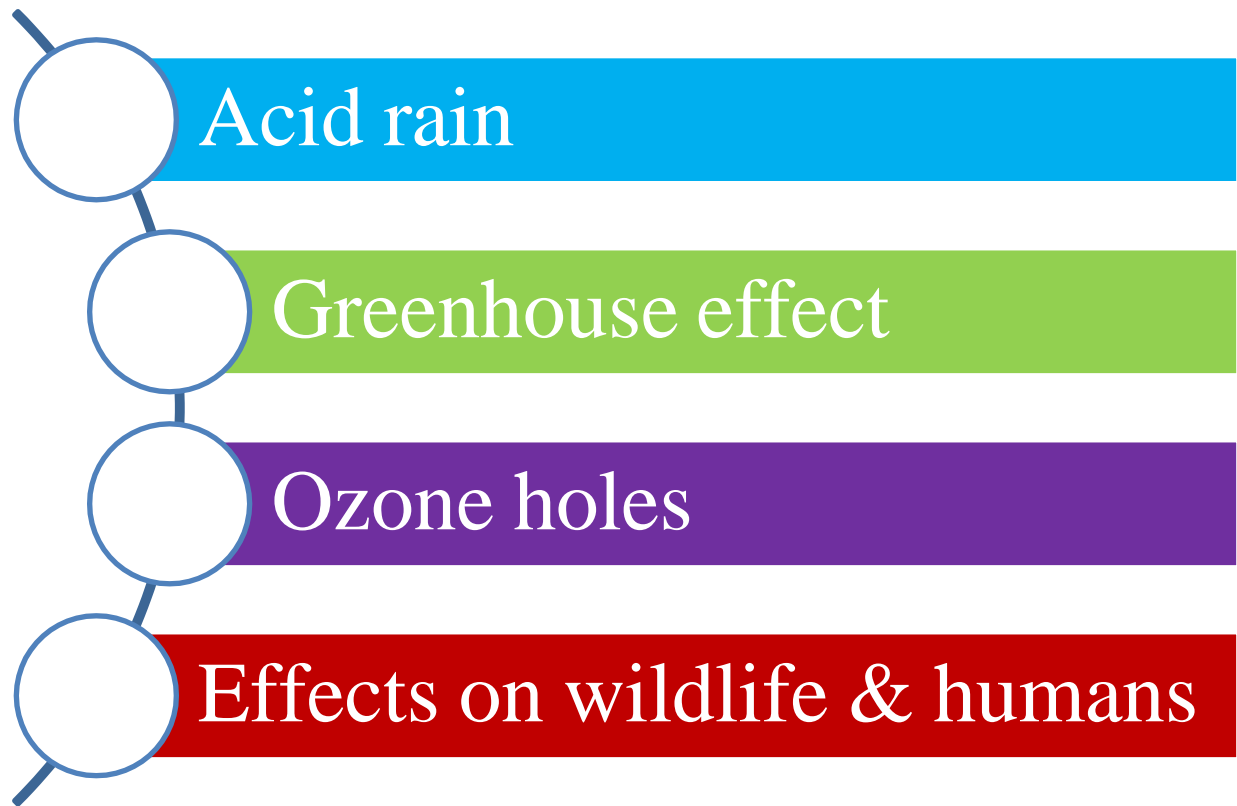


Fig. 2. Selected examples of the effects of pollution leading to climate change.

High levels of toxic waste from industry, noxious emissions from vehicles, fine dust particles from construction work, exhaust fumes from coal plants, adulterated fuel, diesel exhausts, and superfine particles from cooking and garbage fires contribute to the air pollution problem. The harmful contaminants such as carbon monoxide, nitrogen dioxide, and volatile organic compounds, caused by cooking via frying, grilling, or toasting in the indoor environment affect human health to a large extent. Inhaled poisonous fumes such as carbon monoxide produced in an indoor closed space

can cause breathing difficulties, unconsciousness, and even death. The carbon monoxide is an excellent ligand toward the iron present in hemoglobin and can affect the normal functioning. The strong affinity of CO for the Fe(II) in hemoglobin, results in a stable complex, carboxyhemoglobin.

This complexation prevents the normal uptake of oxygen, and asphyxiation can result if CO concentration is high enough in the surrounding air. There is a need for better ventilation standards in kitchens to remove cooking contaminants from inside closed space. The outdoor suspended ultrafine particulate matter will affect the health of vulnerable veterans, children, pregnant women, construction workers, traffic police, and people with a history of respiratory and cardiovascular disorders. The ultrafine and nanoparticle toxicology indicates the link between nanoparticles of titanium dioxide, carbon black, and polystyrene, and respiratory disorders [14,15]. Nanotoxicology, though in its infancy, that studies the interactions of nanoparticles with cellular components and biological systems will help in understanding the mechanism of toxicity and predicting potential human health hazards [16].

The study of the effects of factors such as particle size, composition, solubility, surface chemistry, length of exposure, different structures (nanotubes, nanofilaments), the total number of particles in suspension, degradability and distinctive properties of various engineered nanoproducts and their kinetics within the body system are essential in assessing the toxicity profile and risk to human beings and their harmful effects on our ecosystems. Therefore, the objective of green nanotechnology is to enhance productivity with minimum possible damage to human health and the

environment. It is interesting to note that even naturally occurring nanoparticles such as pollen fragments can cause allergy in some individuals, and viral particles can cause certain diseases. Long-term academic and industrial research projects, the scientific validity of research outcome, substantial research evidence, likely scenarios in the real world, and tested real-world solutions would provide invaluable insight in understanding the interactions between nanomaterials and environment, other development interests, ethical aspects, and legal perspectives. These aspects would eventually lead to framing environmental law and regulation of nanotechnology to serve the greater human good [17].

The rapid growth in the use of fertilizers and pesticides in the last 50 years contributes to contamination of food by persistent residues and certain chemicals enter the food chain through the environmental dispersion [7]. These could cause effects from the slight physical discomfort to dangerous side effects in human beings. Therefore, it is essential to collect water samples from rivers or lakes and monitor its quality frequently by qualitative and quantitative chemical analysis and to track the source of pollutants if their concentrations exceed acceptable levels. Similarly, it is important to monitor air and soil quality at different locations to make them fit for industrial, agricultural and domestic purposes. Environmental laws are necessary to protect environmentally sensitive areas (ESAs) of ecological and landscape significance, from irreparable damage due to pollution. The objective is to prevent further damage, to protect the environment from pollutants, discourage public from activities causing similar damages, and continue to promote environmental

harmony. Particulate pollution from industries can be controlled by using techniques such as gravity settling, centrifugal separation, electrostatic precipitation and use of filtration systems and wet scrubbers.

The wet bio-waste generated in large scale in cities can be processed in the bio methanation plants to generate electricity. The dry waste plastic can be mixed with bitumen that can be used as road topping, as part of plastic waste management. Manufacturing biodegradable plastics that are compostable on a large scale could contribute to a cleaner environment and a greener world. It is important to process biodegradable waste into manure by aerobic or vermicomposting techniques, as part of clean initiatives. Hazardous waste management technologies include incineration, chemical and physical treatment, bioremediation and stabilization and solidification technologies and other treatment technologies are still in the research and development stage.

A comprehensive study involving mapping of particulate pollution in major cities and development blocks around the world, and its acute and chronic impacts on human health, including cancers of the trachea and the lung, will help us to understand the problem in the context in which it occurs. This will allow us to take serious long-term measures to tackle air pollution problem with fresh and special emphasis on improving the present particulate pollution scenario. There is an urgent need to control air pollution in the public health interest and to allow the safe and sustainable development of products, with a comprehensive action plan and effective implementation of a working solution to strive for growth-environment balance. The flow of undertreated drainage water

from urban areas to nearby tanks will result in the accumulation of toxins and it has been observed that the bird population in such ecologically sensitive areas has gradually decreased in the last decade. We need to sensitize civil society groups to issues of fresh air, pure water and productive soil and take appropriate actions using problem solving skills, monitor their progress by suitable follow-up actions. At one level the specific local solution is viable. For instance, protective regulations to preserve or rebuild the rare, threatened or endangered species of plants and animals.

Alternative practices involving integrated efforts are required in our constantly evolving world to have the universal solutions. Integrating renewable sources of power, such as solar and wind on a large scale into the mix and reducing the coal or gas burning power plants would spare millions of tons of greenhouse gases across the globe. Poor energy efficiency in coal power plants reflects the extra coal burning to obtain the same power output. It is important to implement environmental, health, and safety guidelines for phosphatic, nitrogenous and potash fertilizer factories and other chemical manufacturing plants generating toxic metal waste and volatile organic compounds [7]. Hazardous waste reduction efforts in industry results in increased efficiency and lower costs for waste disposal. The recycling efforts also reduce the discharge of pollutants into the environment. Intensive research on immediate and long-term damages to the natural resources due to major oil spills on waters and coastlines is required. Further, determination of specific chemical and biological effects of oil spill, development of oil recovery techniques, clean-up efforts and species restoration programs help recover the ecosystem.

We live in an information age based on connectivity and international early warning systems and network should communicate about the forthcoming environmental events such as earthquake, tsunami, hurricane and epidemics to take timely action to save lives. Establishing a reliable emergency response system and disaster management mechanism will help reduce consequent pollution problems. Proper functioning of trained and professionally skilled manpower could help address the real public health issues due to environmental disasters. A stronger surveillance network involving controlling outbreaks of certain diseases and preventing their spread is essential in case of massive earthquakes to maintain a healthy community.

The population control is the crucial step in protecting and minimizing pollution of the environment because rapid population growth dilutes and defeats all the future plans and public welfare programs. The anti- pollution initiatives such as the banning of plastic bags, no dumping of waste into rivers or no burning waste in public places needs civic consciousness and the fear of fines and prosecution will act as a deterrent. The emergence of eco-consciousness in the world is picking up fast due to some scientific advancements, continued government supports, public participation, and transparent actions through numerous measures and schemes. The results of multidisciplinary research and application development, economic principles, public health ethics, and individual and population benefit should form the foundation for environmental policy making and this helps to disseminate viable and alternative practices to boost the global green development. Proper environmental planning, building engineering and management, use of renewable energy sources,

afforestation, and construction of sewage treatment plants could contribute to world welfare systems. Organizing nature camps, workshops, tree-planting and other events for ecological restoration can lead to long- term environmental benefits.

The establishment of central pollution control boards (CPCB), environment conservation enforcement administration (ECEA) and special operations group (SOG) to carry out detailed analysis of air, water and soil samples from different zones and recommend short-term solutions to prevent further pollution and long-term measures for environmental sustainability. An independent, autonomous body, such as a center for science and environment (CSE) can conduct environmental audits of industries and announce green rating in terms of their performance and compliance compared to the global benchmark. The 3Cs, coordination, cooperation and communication among different countries plays a pivotal role in enhancing the global ecosystem. Strict legislative measures need to be enforced to curb the menace of different types of pollution. “Act Responsible, Think Sustainable” is one of the sustainability slogans that is sending the right message to those committed to the pursuit of sustainable development goals. There is a need to create awareness in students at an early stage of life about the importance of protecting the environment and the dangers of global warming or irreversible climate change or irreparable damage [24-26]. Environmental activism is growing and that has become evident in the environmental justice movement [27]. The bilateral and multilateral relations among countries and continents as well as motivation to manage their networks in a way that maximizes their environmental interests is a challenge [28]. Air quality guidelines limit

set by world health organization (WHO) and environmental protection agency (EPA) distinguishes low pollution, moderate to heavy pollution and serious pollution categories [29].

It is essential to publish the list of various contaminants in air, water and soil and their maximum contaminant levels (MCLs) allowed for a particular application to have controls on pollutant emissions. Toxic release inventory (TRI) and air quality index (AQI) has been developed by EPA and this will help us in developing more environmentally friendly commercial solvents or control some of the many materials that can cause air pollution. Air quality monitoring requires us to carry out real-time data analysis on air pollution in a cost-effective manner using metal oxide sensors at different locations or by mounting on vehicles. Clearly, we have much to learn about proper air, water, and soil management to prevent a serious threat to human health due to contamination of ground and surface water, troposphere and stratosphere air as well as topsoil and subsoil layers. There is a need for distinctive issue-based approach to pollution and dedication to showcase the history of pollution that ranges from traditional pollution patterns to contemporary pollution because of needs and compulsions leading to cross-contamination situation.

NUCLEAR RADIATION POLLUTION

Electricity, being the lifeline of the economy, is an essential need for manufacturing, agriculture and services sectors. The high electricity price cause adverse economic impacts on these

sectors and it will affect the common man in daily life. Therefore, it is essential to pay special attention to ensure efficient and economical power generation, transmission and distribution.

The future state of global energy production and consumption depends on the combined application of nuclear, natural gas, hydroelectric, biomass, solar-thermal and solar-photovoltaic, and geothermal resources [30]. We have to learn lessons from the mistakes of previous nuclear power plant accidents to prevent the harmful effects from recurring, as the use of nuclear energy provide complimentary resource. There is a need to study health effects of exposure to radiation such as alpha and beta particles, gamma rays, X-rays, cosmic radiation and neutrons on the present generation and also cumulative effects of actions today over future generations. The destruction of the Japanese city of Hiroshima, by nuclear bomb, in 1945, instantly killing one lakh people is a grim reminder of the gravity of nuclear war. This nuclear radiation causes congenital defects, mental retardation, immune system destruction and cancers. Radiation-induced DNS transformation can lead to cancer. Containment of radioactive products that are dangerous for thousands of years is the most pressing challenge. Clean-up of contaminated areas, disposition of excess nuclear materials and dismantling of nuclear weapons also contaminate the environment and threatens human health.

The Chernobyl disaster in 1986, involving an explosion and fire, released large quantities of radioactive particles into the atmosphere, and the long-term effects like cancer are still being investigated. The earthquake and tsunami triggered a Fukushima nuclear accident in 2011 forced more than 3 lakh people to move away from the place and it is a tough task to contain the 300 metric

tons of radioactive groundwater leaking into the Pacific. There is a need to adopt new technologies taking into consideration adequate safety measures to meet the energy needs in the 21st century and beyond. Today, protective shielding consisting of lead and other dense metals is used to absorb much of the radiation in the place of work and low- and high-level radioactive waste (LLRW & HLRW) disposal methods are adopted.

The three principal aspects of paying particular attention to the steps on the way of natural processes, having profound mental reflection on the causes or implications of the observed phenomena, and performing theoretical investigation using advanced computational methods and exact experimentation based on modern experimental techniques should provide proper direction to the development of natural science and technology [21]. The successful investigator will provide a platform for modern researchers interested in the subject and set in motion a clean process that would have truly global significance. It is essential to strive to obtain an adequate number of solutions of problems and the clean-up the world activities would also contribute towards a greener planet. The general objective is to identify a variety of underlying factors or potential causes that could be contributing to the environmental issues and offer management plans and lifestyle changes, leading to better health of the people and benign environment. Creating social awareness, widespread environmental education and contributing to conservation of biodiversity as long-term measures will help strengthen enforcement of environmental safety standards, improve air, water and soil quality

and prevent different types of pollution on our pathway to preserve human health and environmental sustainability [3].

The climate change across the planet and global warming could reduce agricultural production and pose the risk of food supply in the future decades. The green chemistry initiative promotes the design and application of chemical products, processes and systems that are compatible with human health and the environment, though the contribution of the chemical industry to pollution is only a small part of the whole picture [Fig. 3]. The major directions involved in the recent research activities include finding alternative starting materials, reagents, transformations, reaction conditions and final products to achieve a more environmentally benign processes, products and systems.

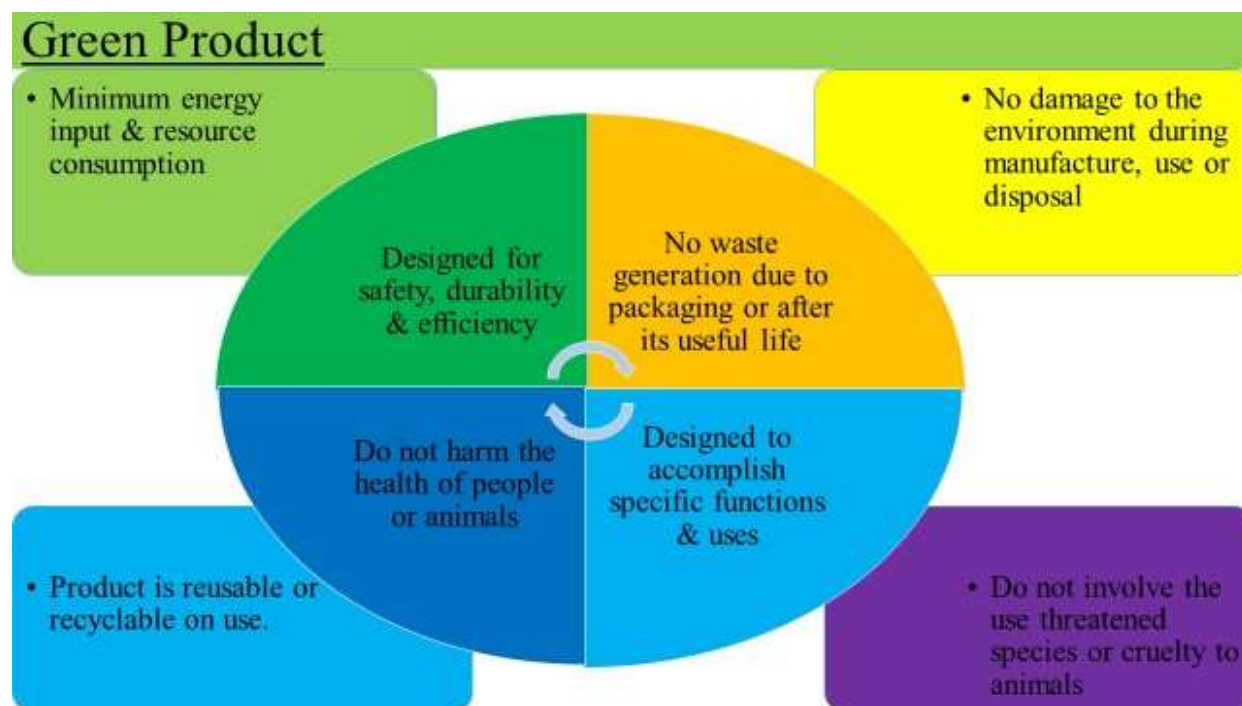


Fig. 3. The major green chemistry principles that can improve environmental quality.

TRAJECTORY OF TOXICOLOGY AND TOXIC LEVELS

The consequences of environmental exposure on human health depends on activation of biochemical reactions leading to a variety of physiological effects. The discipline of toxicology involves the study of adverse biological effects of physical (temperature, radiation) and chemical agents (carbon monoxide, benzene vapor) on living organisms. There are several factors such as the

age, sex, chemical species, dosage as well as absorption, distribution, metabolism and excretion mechanisms determine the overall effect of a particular toxic chemical in a given situation [12].

A toxic screen test is one of the most commonly used diagnostic blood test. It screens the blood for the presence of poisonous substances such as alcohol, amphetamines, antidepressants, antipsychotic drugs, hallucinogens, narcotics and tranquilizers. Some bacteria that invade our body produce poisons that enter the blood stream to cause life-threatening infection such as toxic shock syndrome. The effects of exposure of chemicals can be broadly classified into ‘chronic (long-term) toxicity’ that describes the adverse health effects from repeated exposures that occurs over a longer time period (months or years) (e.g. cancer or allergic reactions) or ‘acute (short-term) toxicity’ that result in adverse health effects immediately after exposure (hours) (e.g. burns from contact with concentrated mineral acids, hydrogen cyanide, phosgene). Chronic lead toxicity may occur from common sources such as lead-based paint in the home, lead smelting and refining or battery manufacturing work at the workplace or combustion of leaded gasoline in the environment. The excessive lead intake in children affects the brain and behavior, and increased blood lead concentrations in adults often resulting in hematological abnormalities. It is a cumulative poison that can cause a wide variety of neurological problems.

The most commonly used therapeutic chelating agent for mobilizing lead is ethylenediamine tetraacetic acid (EDTA) that forms a soluble complex that is excreted through the kidney system of the body. Acute metal toxicity commonly occurs from thallium salts used in rat poison, arsenic

trioxide used as herbicides or the misuse of methylmercury compounds as fungicides in seed treatment. Mercury can enter our body system by inhalation of its vapor, contact with the skin and ingestion of foods or water contaminated with it. Toxic effects include damage to the brain, lungs and kidneys and severe poisoning results in a neurological syndrome called Minamata disease. The acute or chronic mercury poisoning is treated using chelating agents such as dimercaprol and penicillamine that binds to mercury and eliminated from the body through subsequent urinary excretion.

The arsenic absorption from the gastrointestinal tract, ultimately results in its accumulation in the skin, nails and hair. It can be effectively mobilized by dimercaprol (2,3-dimercapto-1-propanol) that can then be eliminated from the body through urine. Other heavy metals that will accumulate in hair follicle include cobalt, chromium, cadmium and tungsten. Many of the reactions that proceed as per certain scheme using the pure chemicals in the laboratory may be different when a natural mix of these chemicals react under the actual conditions of environment. It is important to recall the fact that there is an optimum dose for all essential elements. When an element is insufficient, it results in deficiency disorders, but when it is present in excess, it exerts toxic effects resulting in different types of disorders. For instance, in Parkinson's disease, copper is present in less than normal while in Wilson's disease it is present in excess quantities. Screening for prenatal effects of environmental chemicals, including carcinogens with experimental animals is commonplace and such prenatal exposure to toxins may result in birth defects and developmental

deficits. While high level toxicity may be a sign that the environment is getting damaged, the adverse effects leading to a spectrum of ailments vary from person to person, the concentrations and chemical components of pollutants and the method of measurement also matters, and global effort is required to drastically reduce the extent of pollution.

ABSORPTION ROUTES AND HEALTH EFFECTS

There are several possible pathways of absorption of toxic chemicals into our body system and there is a need to understand general concepts in toxicology. The common avenues of exposure include inhalation of gases, aerosols or powder, ingestion by mouth via contaminated fingers, direct absorption by skin contact or damage or by splashes into the eyes or injection in homicidal poisoning. Thus, the most common routes of absorption of most toxicants are the gastrointestinal tract, respiratory tract and dermal routes. Further, uptake by humans depends on the rate of transport across dermal layers, lung membranes and rate of degradation within the human body and dispersion depends on density, water solubility, volatility and melting and boiling points of the chemicals concerned.

The toxicity testing methods include whole animal testing (in vivo), testing of isolated cells or tissues (in vitro) and in a computer simulation (in silico). Cellular studies have become popular in the last decade because of controllability and low cost. However, they are less reliable than animal studies and extrapolation of results to humans is more challenging. Further, ethical concerns limit

the application of testing methods to clinical trials in humans or exposure in human populations. The median lethal dose, LD50 is the dose required to kill half the members of a tested population (mice or rats) after a specified test duration. The LD50 value indicates relative toxicity of a substance, and it depends on the method of administration. There is a wide spectrum of relative toxicity among the chemical compounds: highly toxic (extremely hazardous), moderately toxic (highly hazardous), slightly toxic (mildly hazardous) and practically non-toxic (less hazardous).

For instance, methyl isocyanate is extremely toxic to humans from acute exposure and water is practically non-toxic and botulinum toxin is one of the most toxic while sugar is one of the least toxic. The relative toxicity of compounds varies within a particular class and DDT is more toxic than malathion, but less toxic than parathion among the insecticides. Organophosphates are more acutely toxic than organochlorine types of pesticides. Depending on the target organ systemic toxicity effect, they are classified as hepatotoxins, nephrotoxins, neurotoxins, hematopoietic toxins, pulmonary toxins and reproductive toxins [10,23]. Other measures of toxicity based on impacts of chemical exposure on the targeted tissue, organ or system include mortality (death), teratogenicity (ability to cause birth defects), carcinogenicity (ability to cause malignant tumors) and mutagenicity (ability to cause heritable change in the DNA). The agents which deprive the tissues of oxygen by displacing or diluting atmospheric oxygen or altering the biological processes that uses oxygen are called asphyxiants. The substances that tend to build up in the body as a result of repeated chronic exposures are known as cumulative poisons. A hematopoietic toxin affects the formation of blood cells while

a hepatotoxin causes damage to the liver cells. A reproductive toxin can harm the gonads, fetus or organs while genotoxins can alter the chromosome structure or number. A neurotoxin may affect neuron functions by inducing cell death, disrupting electrical mechanism or altering neurotransmitter activity.

Further, the biochemical mechanism may be different at low and high doses. The precise molecular mechanism of metal toxicity is uncertain in many cases and there is no effective treatment option either. Though chromium metal is an essential element, it is carcinogenic in Cr(VI) state and occupational exposure in electroplating industry poses risk of health hazards. Zero-valent mercury is highly toxic when inhaled as it can pass through the lung into the blood stream easily. Occupational exposure data indicate that industrial chemicals such as vinyl chloride causes liver cancer and benzene causes cancer and is often linked to leukemia. When more than one hazardous substance are present at the same time, the resulting effect can be greater than the effect predicted for the individual species.

The modern instrumental methods of analysis such as atomic absorption and emission spectrometry, X-ray fluorescence, inductively coupled plasma emission spectrometry, neutron activation analysis and other equipment with advanced features have been contributing to provide meaningful results in assessing exposure to toxic chemicals. The common symptoms of possible overexposure include eye discomfort, breathing difficulty, dizziness, headache, nausea, vomiting and skin irritation. The chemicals affect humans, causing problems such as physical deformity,

respiratory problems, hormonal disturbances, reproductive disorders, kidney damage, skin diseases, gynecological problems, central nervous system disorders, cancers of the liver, blood, and throat and unconsciousness and even death.

The major pathways of elimination of chemicals from our body include urinary excretion route and gastrointestinal tract excretion route. Other less common routes of excretion of chemicals include sweat, saliva, hair, nails, tears, milk, exhalation, and biliary excretion. The pharmacokinetic model considering the absorption, distribution, biotransformation, and excretion processes as a function of time is extremely useful in monitoring biological and environmental impacts and to arrive at reasonable dose-response relationships [18]. It is important to develop a deeper and more comprehensive understanding of the toxicological implications of ecosystems by considering it as a complex mixture of several chemicals in different concentrations. A firm understanding and application of the underlying green chemistry and green engineering principles fuel scientific progress and technological breakthroughs [3,22].

SAFETY PRECAUTIONS INVOLVING HAZARDOUS PRODUCTS

It is important to read the chemical safety information available in Safety Data Sheets (SDS) on the existing chemical catalogue and follow the recommendations for safe use and disposal of the materials that we use in the laboratory experiments [31]. For example, the common gases can be categorized as simple asphyxiants (N₂, CO₂), toxic asphyxiants (CO, HCN, H₂S) and irritant gases

(Cl₂, NH₃, NO₂, O₃, SO₂, HCl) and their toxic effects depend on several factors such as duration of exposure, history of health condition, concentration of the substance, age of the individual and the organ system affected. Further, the effect of irritant gases in the respiratory tract depends on their ability to denature proteins, water solubility, and lyophilic character. These potential occupational hazards could be minimized or eliminated by taking appropriate safety precautions while working, such as the use of personal protective equipment, improved design and maintenance, and proper interdisciplinary training in safety aspects and impacts.

We have to blend the right benchmark principles of safety into work practice by controlling our own thoughts and a host of more specific actions in the right safety spirit. Further research on the toxicology of chemical compounds is required to have a better understanding of toxic mechanisms and to have effective clinical medical practice to treat environmental and occupational exposure to such chemicals. The quality, effectiveness and safety of medicines and quality of services in the pharma sector are of crucial importance and circulation of spurious drugs can lead to major side effects in generally healthy people and adverse medical consequences in patients with other health complications. Therefore, stringent penalty for manufacture and sale of such drugs should be implemented, enforcing good manufacturing practices. The recent developments in genetically modified crops suggest that a detailed study of the long-term adverse effects of such products as potato, corn and apples on human health can indicate their usefulness in our daily lives [32].

The use of calcium carbide in artificial ripening of mangos produces acetylene gas that is a potential human carcinogen and toxic to aquatic organisms and it is better to use ethylene gas from the food safety point of view. It is essential to phase out the use of CFCs in refrigerators and auto air- conditioning systems eventually and alternatives such as hydrofluorocarbons (HFCs), 1,1,1,2-Tetrafluoroethane ($C_2H_2F_4$) should be used by all the manufacturers. Annual limit on the mass per unit volume for fine particles with diameters less than $2.5\ \mu m$ in the air should be set to $15\ \mu g/m^3$, as part of ambient air quality standards [29]. All industrial effluents should be subjected to suitable treatment and smokestacks must be installed to trap smoke particles. Occupational safety and health administration (OSHA) law and regulations, recommends daily permissible noise level exposure and other workplace health and safety standards [17]. The iceberg model of toxic chemicals contains a small portion of compounds proven to be harmful at the top, slightly larger portion of partially proven cases, large chunk being not yet recognized cases in the middle, and finally many at the bottom will never be recognized due course due to difficulties of detection. Today, many university, industrial and government laboratories are involved in environmental research efforts and the major advances in this interdisciplinary topic may lead to practical solutions to the problem of hazardous waste.

BIOLOGICAL RESPONSE AND TOXICITY ASSESSMENT

The possible dangers of nanoparticles are due to the high surface to volume ratio, which can make them highly reactive and they can penetrate through cell membranes in biological systems, causing unknown interactions in real-world scenarios. The silver nanoparticles used in socks to reduce foot odor are released on washing that may destroy beneficial bacteria in the soil that help in breaking down organic matter. The respirable suspended particulate matter (RSPM) is an indicator of pollution in the air. The particles smaller than about 10 micrometers (PM₁₀), can settle in the lungs and cause health problems, while those having size smaller than 2.5 micrometers (PM_{2.5}), tend to penetrate into the gas exchange regions of the lung, and very small particles (< 100 nanometers) may pass through the lungs to affect other organs. There is a safe and dangerous level for every substance (toxicant or benign compound) depending on the dose-response graph where experimental data of different amounts of substance administered are plotted against frequency of some measurable physiological effects.

In general, higher dosage cause toxic effects in the organism while excessive dosage lead to lethality. The larger or steeper slope implies a toxic compound with a smaller range between the effective and toxic doses. The shape and slope of the curve could indicate toxicological end point, toxic dose, lethal concentrations, and lowest observed adverse effect level. The extrapolation of results for the effect of exposure to environmental chemicals is more challenging. Any extrapolation of results regarding physical and chemical properties from one nanoparticle to another closely related

one must take into considerations based on a quantitative structure activity relationship model (QSARs) [33].

Therefore, it is essential to develop specific approaches to testing their effects on human health and the environmental impact [34, 35]. There is a need to collect reliable data on exposure for environmental chemicals and response result to obtain information that help in categorizing and comparing the safety of different compounds and take proper risk management actions. The hazard identification by cellular or animal studies and chemical structure-property relationship is the first step in the risk management. The acceptable daily intake is calculated based on extrapolating relevant doses for humans from animal studies.

The exposure assessment must consider the frequency, duration, severity, and route in a population segment. The risk characterization based on the intensity and nature of an effect helps in the formulation regulatory process for implementation. Today, identification of toxicants is done through high-throughput screening of suspected compounds with known toxicity related targets and understanding their biotransformation mechanisms within the human body. The metabolically distinct distribution mechanisms can have an influence on the action of a toxicant. Relevant information and appropriate models to identify toxicological hazard and risk assessment help us to solve specific sustainable chemistry problems pertaining to health and the environment. The study of toxicity and resistance potential of selected test microorganisms could reveal the genetic basis or biochemical mechanisms of resistance.

The bioconcentration of pesticides in fish and biomagnification or bioamplification at the top of the food chain due to consumption of larger quantities of smaller animals affect the environment. For instance, dramatic decline in the population of some birds such as eagles, vultures, sparrows and falcons is caused by high concentrations of pesticide DDT in earlier studies or continued use of a harmful pain relief drug, diclofenac, a non-steroidal anti-inflammatory drug to treat cattle, was responsible for the great increase in bird mortality. The catastrophic decline of vulture numbers around 2006, has stabilized in the recent past. There is a need for a comprehensive environmental evaluation of veterinary drugs, careful planning to remove all known poisons, biodiversity management strategies, a ban on the use of toxic drugs, minimum consumption of natural resources, management of the sewage system and other ecological diversity conservation efforts.

The information on specific structural features of foreign chemicals that influence biological response (toxic tissue injury) on exposure helps us in understanding the adverse interactions between chemicals and biological systems and to reduce potential toxicity during the synthesis of new compounds by modifying functional groups. Sometimes, the toxicity of different isomers may be drastically different just like the therapeutic activity of certain isomers. The chemical safety assessment of emerging chemical technologies would have an impact on worker safety and the environment. The contamination of food with chemicals has to be determined to prevent the amount of poison we consume in the name of food. The rise of many diseases could be related to the contaminants present in processed food products from bread to branded items. It is important to

create awareness about safe foods and the processed food products containing food additives, preservatives, colorants, and flavors must be assessed for their potential long-term toxicity risk. A proper food safety mechanism, including stronger food regulations, strict enforcement, proper labeling, stringent quality control, and monitoring the entire food chain from farm or factory to the fork is necessary to prevent harm caused by unsafe food intake.

It is essential to create awareness about the importance of living in harmony with nature and organic farming practice provides a holistic approach to prosperity and the environment. It is extremely important to collect human data on accidental or routine exposure to chemicals and obtain meaningful information from critical analysis and proper interpretation of data in such cases. The range of chemicals could include environmental pollutants, industrial compounds, petrochemicals, pesticides, pharmaceuticals, hazardous wastes, and chemical warfare agents. The study of possible interactions of drug formulations in liquid or suspension form with plastic bottles over a period of time could indicate their potential toxic effects in humans. This will help us to understand real-world toxicological issues and to find out appropriate ecofriendly solutions. A new study on the oil spill in the Gulf of Mexico has found higher levels of many oil-related compounds like polycyclic aromatic hydrocarbons and volatile organic compounds, indicating the need for comprehensive chemical analysis of seafood samples and review of seafood safety.

ECO-TOXICOLOGICAL ASPECTS AND ADVERSE EFFECTS

Ecotoxicology deals with the study of the effects of toxic substances on ecosystems. It is essential to assess the environmental damage from pollution on plants and animals and predict the consequences of human activities on various ecosystems. The tools of assessment range from toxicity tests of individual chemicals on organisms, modern instrumental analysis to detect the presence of toxicants, and field surveys to characterize the damaged ecosystem. Hazardous substances with properties that make them dangerous or potentially harmful to the environment must be classified into extremely hazardous, highly hazardous, mildly hazardous and less hazardous types. The negative impact on the environment could include adverse effects on river basins, water, air and soil quality, wildlife and biodiversity and on forests. Alkaline soils can neutralize the acid deposition and can withstand acid accumulation without adverse ecological effects for a longer time.

Some areas are particularly vulnerable to acid deposition depending on a combination of climatic and geologic factors. The effects of acidification can be observed in lakes where sudden increase in acidity can produce severe chemical shocks to aquatic life. The gradual forest decline in some parts of the planet has been linked to acid rain and other air pollutants in woodlands. Acid rain can also affect the yields of certain crops, cause damage to some materials (Al, Cu, Ni, Marble, and Limestone), pose visibility problems and human health effects. Persistence of chemicals in the environment depends on the rates of atmospheric oxidation, aqueous hydrolysis, microbial degradation, photolysis and adsorption processes.

The environmental condition-toxicity relationships play an important role in determining the response of organisms. It is practically feasible to test a few representative species in the food chain and sample chemicals under controlled laboratory conditions, considering the complexity of the ecosystem where testing of the billions of species on this planet is impractical. Though LD50 is a common measure of toxicity, it does not consider toxic effects that are serious but not lethal and chronic toxicity effects. Further, cross-species extrapolations from animals to humans may impose some limitations and in certain cases a chemical relatively safe in rats may be highly toxic to humans. It is important to recall the old adage that “even nectar is a poison if taken in excess.” It is known that table sugar administered in high doses can be toxic with high LD50 value. Nickel is an essential trace element in some animal species; it has toxic properties in high doses and one of its compounds, nickel tetracarbonyl, is a probable human carcinogen. Methylmercury present in fish is much more toxic than inorganic mercury found in other food products. Aspirin, when taken in large doses can lead to poisoning. The transformation of one species to another by processes in the environment has to be taken into consideration.

The environmental survey around the world using a multistage representative sample design will have long-term environmental implications and there is a need for a global welfare program. We will be in a position to relate the impacts of a chemical product, process or system to its effects in the environment, after establishing a reliable database containing information about the impact of chemical species on different organisms and the test methods adopted in such cases. It is now

considered important to adopt a reliable and a cumulative environmental impact assessment (EIA) of all development projects rather than using stand-alone treatment. The expert committee can study and recommend or reject the projects that have potential to cause a significant impact on the environment. The detailed study of every aspect of ecotoxicology from interactions between small particles to their effect on ecosystems, people and materials in our daily life and measurement of the impact of these particles as they fly through the environment help us in better understanding of the subject matter. We must focus on combining exhaustive academic and industry knowledge with advanced analytics to develop environmental models for setting and achieving global green global outcomes (Fig. 4). A mutually profitable long-term partnership, continuous support and cooperation among people in different fields such as software, medical, food processing and mechanical engineering fields is useful and important.

Performance improvements in activities like environmental engineering tasks, processes, and service operations using technology, products and systems, would result in value creation and transformation. A long-term vision and strategy for sustainable development, adopting modern practices and improving technology, quality and safety standards, good work environment, and mechanisms to improve operating efficiencies will help in taking more concerted global action to address the climate change challenge.

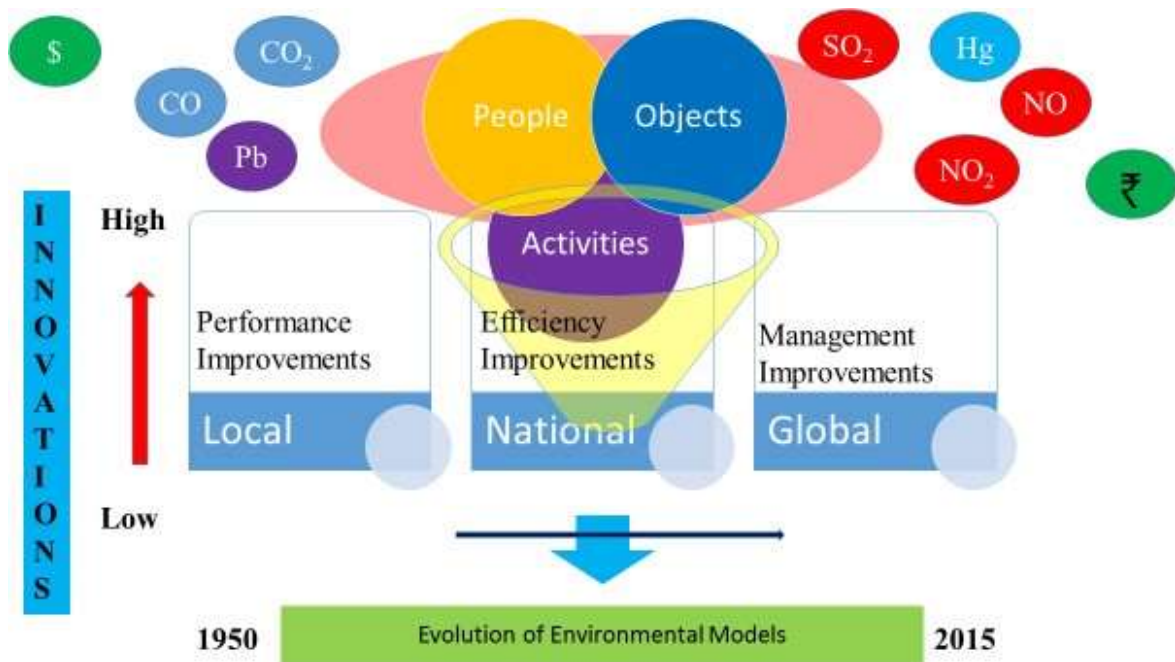


Fig. 4. Different categories of improvements and innovations at various levels in the evolution of environmental models.

INCIDENTS AND ACTIONS REQUIRED

Aerial spraying of an organo-chlorine pesticide, endosulfan, on the cashew plantations in India as a measure to control the tea mosquito bug, resulted in acute poisoning killing many fish, frogs, crabs and other animals. This has also caused debilitating diseases and other health complications such as cancer, skin diseases and infertility due disruption of the endocrine system. Unfortunately, pesticide poisoning is the main form of farmers' suicide. Bhopal gas tragedy in India, due to deadly

methyl isocyanate (MIC) gas, in 1984, that killed nearly 4000 people and injured about 200,000 people should be the eye-opener for all the earlier events of loss of lives due to chemical products.

The Exxon Valdez oil spill in 1989 has resulted in killing many birds, fish and other marine species due to short-term effects of toxicity of various components and indirect long-term effects such as habitat loss or lack of food. The design, commercial application and use of processes and products should minimize the impact on human health and the environment when pursuing sustainable development. Adequate and timely actions along with awareness campaigns by mobilizing the masses are required by both the government and the general public to keep the pollution under control [Fig 5]. The disciplined individuals committed to the cause of pollution reduction can contribute in various capacities in taking the green global development to a new level. Similarly, creative collaborations on climate change projects among different countries in the world will have long lasting implications globally and can deliver the expected dividends that reflect the emergence of strong ecosystem.

To achieve socioeconomic and scientific objectives, strong direct functional links must be built between academic institutions and other sectors to ensure effective cross-sectoral collaboration. Green and sustainable manufacturing are actually applicable to several sectors such as automobile, construction, chemicals, electronics, power, and consumer goods and there is an urgent need to evolve a strategy to spread an operational framework on a collaborative basis. Reliable and strategic partnerships between different countries in certain key sectors such as water supply and waste

management, food service management, transportation, power transmission and distribution, space cooperation, nuclear energy and defense, and urban infrastructure development is required to make significant overall progress.

It is important to have a memorandum of understanding (MoUs) between the collaborating nations or institutions, including clauses on investment commitments, sharing of responsibility and liability, and quality control and timely delivery. The establishment of enforcement directorate (ED) and carbon footprint exchange agreements at the global level would have enormous consequences to promote a better climate for life. The intergovernmental panel on climate change (IPCC) is the leading international body for the assessment of climate change and they have published the fifth assessment report [36]. The ecological movement across the world for a greater growth-environment balance is gaining momentum in the recent past. Today, collective and coordinated effort is a prerequisite to undertake different activities to drastically reduce pollution, minimize use of our precious natural resources and protect the environment. The inspiration to sustain the environmental reform campaign comes from the active participation of a large number of people and dedicated efforts by communities, civil society groups and organizations.



Fig. 5. Summary of actions required with strong close links to boost productivity and growth without environmental damage that will benefit all.

The following critical aspects need to be considered for the production and use of chemical products, and functioning of other systems on the pathway to sustainability:

1. Maintain a safe operation of chemical industries with a light ecological footprint and improve existing safety and security measures.
2. Risk assessment of toxic compounds used or produced to reduce impact on the environment.
3. Location of chemical plants away from heavily populated settlements.

4. Protection plans for workers and residents in case of disaster and proactive measures to minimize damages.
5. Pollution prevention at the source, recycling and disposal in that order, in an environmentally safe manner.
6. Global level action plan for achieving ecological restoration and sustainable development that will have profound implications and new enforcement strategies.
7. Budget allocation and commitment from management in implementation of pollution control and prevention programs.
8. Increasing sources of renewable energy and decreasing use of dwindling resources.
9. Reforestation programs and forest conservation efforts as part of sustainable management of forests.
10. Decrease global carbon footprints due to the transportation, residential and manufacturing sectors.
11. Use of eco-friendly technologies and sustainable agricultural practices for better results in crop production and for preventing extensive ecosystem damage due to development pressure.
12. Conduct research on less toxic chemical products, greener alternative processes, catalysis, kinetics and reaction engineering from benign environmental perspective.
13. Carry out life cycle analysis of a particular product or process to reduce the environmental impacts, at different stages of the overall process or use.

14. Develop green technologies and create a reaction system that can be scaled for production using tools like reaction conditions, catalysts or reactors, to improve reaction performance and reduce the environmental footprint.
15. Conduct study on the environmental contamination and toxic effects of human exposure of unburned hydrocarbons, nanomaterials and other particulate matter.
16. Proper environmental laws and procedures, transparency in functions and policy implementation aspects to prevent ecological disasters and to take forward the sustainable growth agenda for action with growing global connectivity.
17. Review of environmental clearances of mega-projects that would adversely impact aquatic and terrestrial biodiversity.
18. Strengthening safety base and establishing mass contact to create more awareness about sustainability aspects and impacts.
19. Attract more investments by nations in environmental protection and tackling environmental problems.
20. Establishing a global green network to advance knowledge and promote state-of-the-art technologies and distinct ideological perspectives to have a clean environment.

CONCLUSIONS

We have to look beyond our limited need and condition and sustainability is a prerequisite for any development paradigm and there is a link between the basic chemical principles and practical environmental issues. Harmful inorganic and organic chemicals discharged from agriculture, industry, transport, mining and urban centers as well as heat, noise, light and nuclear radiation contribute to particular environmental pollution issues. The root causes of pollution include human population explosion, rapid industrialization and urbanization, overexploitation of nature and natural phenomenon.

The study of the nature and quantity of specific pollutants, effects on humans and animals, sources, reactions and pathways, assessment and pollution control methods will help us to have more meaningful connect with life and nature. Technological solutions involving efficiency, ecological conservation, environmental laws and regulations, and healthier lifestyles help us to prevent pollution problems and adopt a more sustainable way of living. Ecofriendly design of chemical products, processes and systems that reduce or eliminate the generation or use of hazardous substances help in control of environmental pollution.

The active participation of every citizen is required in controlling different types of pollution and to witness the journey of impressive overall growth in the near- and long-term future with the delicate balance between economic growth and ecological security. The construction of energy-efficient buildings, efficient transportation systems, efficient lighting programs, good manufacturing

practice regulations, use and disposal of toxic chemicals and nanoproducts, and incentives to industries to reduce emissions will go a long way in improving the confidence of people across the globe and to address key challenges ahead through innovative techniques and interdisciplinary practice. Long-term measures are a necessity to benefit the global economy as a whole and corrective actions for creating a sustainable planet are required where there are some early warning signs [37-41].

There are many ways in which we can reduce our individual environmental footprint by adopting one or more sustainable personal practices and at the collective level, it can make a huge difference with the power of multiplying effect. The second international conference on evaluation of climate change and development was held in 2014. Such conferences on climate change and global development can offer serious and adequate recommendations so that the reasonable needs of people at all levels from diverse fields are taken care of without conflicts and contradictions and to balance private interest with the larger interest of society.

It is important to promote human activities that reflect universal values and contributes to the common good of the global community in addition to their personal development, as a true measure of 'green growth' is sustainability and social stability. It is essential to develop socially and environmentally responsible individuals and leaders by taking a holistic view of living in harmony with nature. Sharing universal and scientific knowledge will bring about unity in thought in diversity on this transformative journey towards sustainable development.

The consequences are evident in the fragile ecology and with proper planning depending on specific geographical conditions, their impact can be reduced. In this context, it is essential to develop humanitarian ethics in business practice that advances the common good of human development considering eco-sensitive zones and a positive attitude toward biodiversity, and prosper within society. The green development model will be successful in future decades by following the growth trajectory different from the past and depending on individual contributions and collective and comprehensive development efforts taking into consideration the parameters of the environment. The important components of sustainable development include environmental education and awareness, stabilization of population, conservation of ecological diversity, control of air, water and soil pollution, recycling of wastes and residues, use of renewable energy resources and planning of integrated use of ecosystems. It remains to be seen whether the identification of hazards and risks from chemical species to environmental, animal and human health, political will to build a green globe and implementing green initiatives through several steps in the regulatory process would eventually lead to the sustainability of the planet.

REFERENCES

1. Klaassen, C.D. Ed., Casarett & Doull's Toxicology: The Basic Science of Poisons, Mc Graw-Hill, New York, 2008.
2. <http://sis.nlm.nih.gov/enviro/toxtutor/tox1> (accessed June 2020).
3. Johnson, D.E., G.L. Anderson. Green Chemistry and Toxicology. Chapter 11 in Green Chemistry and Engineering: A Pathway to Sustainability. M. Abraham, A.E. Marteel- Parrish, (Eds). New York, Wiley & Sons, 2014, 325-349.

4. <http://chemlabs.uoregon.edu/safety/toxicity.html> (accessed June 2020).
5. R. Luttge, *Microfabrication for Industrial Applications*, Elsevier, Oxford, 2011.
6. www.esrl.noaa.gov/csd/assessments/ozone (accessed June 2020).
7. www.ifc.org/.../Final - Phosphate Fertilizer Plants.pdf (accessed June 2020).
8. S.S. Brown, Ed. *Clinical Chemistry and Chemical Toxicology of Metals*, Elsevier, Amsterdam, 1977.
9. Richter, *Beyond Smoke and Mirrors: Climate Change and Energy in the 21st Century*, Cambridge University Press, New York, 2010.
10. S.S. Brown, D.S. Davies, Eds. *Organ-directed Toxicity Chemical Indices and Mechanisms*, Pergamon, Oxford, 1981.
11. E. Pooley, *The Climate War: True Believers, Power Brokers, and the Fight to Save the Earth*, Hyperion, New York, 2010.
12. F.J. Verheijen, "Photopollution: Artificial light optic spatial control systems fail to cope with. Incidents, causation, remedies". *Experimental biology*, 1985, 44, 1–18.
13. P. Cinzano, P. F. Falchi, C.D. Elvidge, K.E. Baugh, "The artificial night sky brightness mapped from DMSP Operational Linescan System measurements" 2000.
14. M. Wautelet, *Nanotechnologies*, Institution of Engineering and Technology, London, 2009.
15. J. Kim, *Nanomaterials*, Apple Academic Press Inc., Oakville, 2010.
16. C. Walters, E. Pool, V. Somerset. *Nanotoxicology: A Review*, Toxicology - New Aspects to This Scientific Conundrum, Sonia Soloneski and Marcelo L. Larramendy, IntechOpen, 2016, DOI: 10.5772/64754.
17. <https://www.osha.gov/law-regs.html> (accessed June 2020).
18. G.F. Nordberg, Ed., *Effects and Dose-response Relationships of Toxic Metals*, Elsevier, Amsterdam, 1979.
19. P.D. Williams, G.H. Hottendorf, Eds., *Comprehensive Toxicology*, Elsevier, Amsterdam, 1997.
20. A. Lyubimov, *Encyclopedia of Drug Metabolism and Interactions*, John Wiley and Sons, New Jersey, 2012.
21. B. Reisfeld, A. Mayeno, Eds. *Computational Toxicology*, Vol.II, Springer Science, New York, 2012.
22. P.T. Anastas, M.M. Kirchhoff, *Origins, Current Status, and Future Challenges of Green Chemistry*, *Acc. Chem. Res.* 2002, 35, 686-694.
23. A.M. Richard, C. Yang, R.S. Judson, *Toxicology Mechanisms and Methods*, 2008, 18, 103-118.
24. P. Buell, J. Gerald, *Chemistry in Environmental Perspective*, Prentice Hall, New Jersey, 1994.
25. T.G. Spiro, W.M. Stigliani, *Chemistry of the Environment*, 2nd Edn., PHI Learning Pvt. Ltd. New Delhi, 2009.
26. D. Tilman, C. Lehman, *Human Caused Environmental Change: Impacts on Plant Diversity and Evolution*, 2001.

27. H. Christopher, Foreman, Jr., *The Promise and Peril of Environmental Justice*, Brookings Institution Press, Washington, D.C., 1998.
28. www.unep.org/pdf/recycling_from_e-waste_to_resources.pdf (accessed June 2020).
29. www.epa.gov/air/criteria.html (accessed June 2020).
30. A. Srivastava, I. Roy, *Bio-Nano-Geo-Sciences*, Ane Books Pvt. Ltd. New Delhi, 2009.
31. <https://www.msds.com/> (accessed June 2020).
32. J. Freedman, *Genetically Modified Food: How Biotechnology Is Changing What We Eat*, The Rosen Publishing Group, 2009.
33. T.W. Schultz, M.T.D. Cronin, J.D. Walker, A.O. Aptula, *Journal of Molecular Structure*, 622, 2003, 1-22 (QSARs).
34. www.euro.who.int/data/assets/pdf/0005/78638/E90038.pdf (accessed June 2020).
35. Chellaney, *Water, Peace and War- Confronting the Global Water Crisis*, Oxford University Press, New Delhi, 2015.
36. www.ipcc.ch > 2019.
37. G.D. Friedman, *Primer of Epidemiology*, 3rd Edn., McGraw Hill, New York, 1988.
38. A.K. De, *Environmental Chemistry*, 6th Edn., New Age International Ltd., New Delhi, 2006.
39. G.J. Miller, *Living in the Environment*, Wadsworth Publ. Co., California, 1994.
40. Shvedova, A.A. Kagan, V.E., Fadeel, B. *Annu. Rev. Pharmacol. Toxicol.* 50, 2010, 63- 68.
41. M. Fan, C -P., Huang, A.E. Bland, W. Wang, L. Slimane, I. Wright, Eds., *Environmental nanotechnology*, Elsevier, Oxford, 2010.

AFRICAN JOURNAL OF CHEMICAL EDUCATION

AJCE

GUIDELINES FOR AUTHORS

SJIF IMPACT FACTOR EVALUATION [SJIF 2012 = 3.963]

The African Journal of Chemical Education (AJCE) is a biannual online journal of the Federation of African Societies of Chemistry (FASC). The primary focus of the content of AJCE is chemistry education in Africa. It, however, addresses chemistry education issues from any part of the world that have relevance for Africa. The type of contents may include, but not limited to, the following:

RESEARCH PAPERS reporting the results of original research. It is a peer-reviewed submission that deals with chemistry education at any level (primary, secondary, undergraduate, and postgraduate) and can address a specific content area, describe a new pedagogy or teaching method, or provide results from an innovation or from a formal research project.

SHORT NOTES containing the results of a limited investigation or a shorter submission, generally containing updates or extensions of a topic that has already been published.

REVIEWS presenting a thorough documentation of subjects of current interest in chemical education.

LABORATORY EXPERIMENTS AND DEMONSTRATIONS describing a novel experiment/demonstration, including instructions for students and the instructor and information about safety and hazards.

SCIENTIFIC THEORIES describing the scientific, historical and philosophical foundations of theories and their implications to chemical education.

ACTIVITIES describing a hands-on activity that can be done in the classroom or laboratory and/or as a take home project,

INDIGENOUS KNOWLEDGE AND CHEMISTRY IN AFRICA as a special feature that addresses the relationship between indigenous knowledge and chemistry in Africa. It could be in the form of an article, a note, an activity, commentary, etc.

LETTER TO THE EDITOR: A reader response to an editorial, research report or article that had been published previously. The short piece should contribute to or elicit discussion on the subject without overstepping professional courtesy.

All manuscripts must be written in English and be preferably organized under the following headings: a) **TITLE**, Author(s), Address(es), and **ABSTRACT** in the first page, b) **INTRODUCTION** reviewing literature related to the theme of the manuscript, stating the problem and purpose of the study, c) **METHODOLOGY/EXPERIMENTAL** including the design and procedures of the study, instruments used and issues related to the reliability and/or validity of the

instruments, when applicable, d) **RESULTS AND DISCUSSION**, e) **REFERENCES** in which reference numbers appear in the text sequentially in brackets, each reference be given a separate reference number, *et al* and other notations like *Ibid* are avoided, and finally f) **ACKNOWLEDGEMENTS**.

When submitting a manuscript, please indicate where your manuscript best fits from the above list of categories of content type. All enquiries and manuscripts should be addressed to the Editor-in-Chief: email eic@faschem.org, PO Box 2305, Addis Ababa, Ethiopia.