HARMONISATION OF ANALYTICAL CHEMISTRY CURRICULA- A WORKING DOCUMENT

Report prepared by the SEANAC Committee and the SACI Analytical Division Steering Committee

1. SUMMARY

This document seeks to identify the challenges faced by Analytical Chemistry as a discipline in science, and attempts to map a four year Analytical Chemistry curricula as a working guideline.

The document seeks to interrogate and to some extent answer the following questions as part of the continuous discussions about the nature in which the Analytical Chemistry field should be driven:

- What Analytical Chemistry is?
- Where should Analytical Chemistry go and what should be the future of Analytical Chemistry look like?
- What are the components of Analytical Chemistry that need to be guarded?
- Is there a clear understanding of Analytical Chemistry in Africa among lecturers that teach the subject and others?
- Who are the customers for Analytical Chemistry?
- Who is the chemical Analyst?
- What do we expect from a General Chemistry Graduate?

This curricula document is a report of the discussion that took place on the 12-13th August workshop at Birchwood Hotel, Kempton Park in Johannesburg where participants gave input after listening to presentations from various areas such as mining, health, food, pharmaceuticals, etc, where analytical chemistry is applied as well as from speakers from East, West, East, North Africa and Southern Africa. The presentations and discussions highlighted the competence required for an undergraduate student (four year graduate student) in analytical chemistry to have to be fit for purpose. This August meeting was also attended by the members of the Analytical Division of the South African Chemical Institute (SACI) as well as various chemical industries in South Africa who also presented their perspectives on the application of analytical chemistry in their operations.

2. ADDRESSES FROM AFRICAN ACADEMICS AND FROM CHEMICAL INDUSTRIES

Introduction-Prof Nelson Torto (Rhodes University, South Africa)

Prof Torto opened the workshop in his capacity as the secretary general of the African Network of Analytical Chemists (SEANAC) and as the Chairman of the SACI Analytical Division by giving some introductory remarks. He briefly informed participants about (a) why there was a need for harmonisation of curricula (b) what progress had been made and (c) outlined the task for the workshop.

He informed the participants that SEANAC and the analytical Division of SACI were mandated to promote the discipline of Analytical Chemistry and to ensure that the practise was aligned

with the times as well as societal needs. In particular he indicated that through workshops and symposia, SEANAC and SACI had taken responsibility. As an update he informed the participants that recently SAVI had held a consultative workshop themed around the triple helix. The SACI workshop had provided a platform for academia, industry and government to consult with each other. It was clear in the workshop's outcome that there was a need to train, retrain as well as maintain standards to ensure the reputation and professionalism of the discipline were maintained.

Prof Torto told the participants that prior to the workshop, SACI ad SEANAC had engaged a group of experts from various Universities and countries in order to draft a Four year analytical Chemistry program that would serve as a working document. He concluded by informing the participants that the task for the workshop was to:

a) Listen to various practises and what influences them from a geographic perspective of Africa (North, East, West and South)

b) Listen to presentations from the mining industry, government, health sector as well as societies in order to understand the environment for the practise.

c) Evaluate and populate components of the working document

d) Propose a way towards the development of a harmonised curricula.

North African Perspective-Prof Nabil Bashir (University of the Gezira, Sudan)

Prof Bashir pointed out that most core Analytical Chemistry subjects are included in the current programs, but that perhaps they need repackaging when teaching them and that it should come out that Analytical Chemistry is a discipline of its own within Chemistry with relevance to other disciplines. Prof Bashir explained that Analytical Chemistry is a science and a profession, and a tool to other disciplines. He maintained that Analytical Chemistry must be given the required time within the BSc curricula. He added, however, that specially designed Analytical Chemistry Courses are required for the other faculties or departments that require Analytical Chemistry as a tool, e.g. Faculty of Pharmacy, Departments of Food Sciences, Food Technology, Dairy Sciences, Meat Sciences & Technology, Pesticides, Toxicology, Horticulture, especially natural products, aromatic & medical plants, physiology and post-harvest physiology, and Soils. Faculties of Education (Departments of Chemistry), Medicine, Environment & Natural Resources, Engineering (Chemical Engineering) and Veterinary Sciences could also benefit from these specially designed courses.

Prof Bashir discussed that a General Chemistry Course must have credit hours for both the theory & the practical, and that synchronization of lecture topics with labs is necessary. He raised a concern that some instructors use the lab time for lectures (compensation) to finish the course (theory) on time. He added that the pre-requisites for the more advanced Analytical Chemistry Courses must be grouped under one course or specified in early chapters of the textbooks (The basic concepts & terminologies required for Analytical Chemistry). He also added that organic and physical chemistry components related to the analysis *per se* must be dealt with clearly stating their importance and position for/within the analytical process & separation techniques, *e.g*. pH, pKa, Ka, D, K_d, affinity, activity, polarity, acidity, alkalinity, density, viscosity, volatility, vapor pressure, and thermodynamics. He also mentioned that the focus must be on the mathematical concepts related to physical & analytical chemistry only instead of pure mathematical courses which are repelling & boring to the students and time consuming.

Prof Bashir alluded to the fact that the currently produced B.Sc. Gen. or Hons chemist is not really ready to handle the job before being trained by his/her superiors (in-service), and that this chemist has strong competition with graduates of the other faculties (more specialized). He clarified that several faculties in the north of Africa offer hyphenated chemistry degrees: *e.g*. Chem-Botany, Chem-Zoology, Chem-Geology, Chem-Physics, etc, and that as teachers the graduates from these programmes struggle to compete with those from the Faculty of Education. Prof Bashir proposes a way forward as to have a Faculty for Chemistry instead of a Department of Chemistry. This faculty would graduate; a general Chemist (the currently proposed curriculum), physical chemist, organic chemist, analytical chemist, biochemist, and related fields such as chemistry of natural products, agrochemicals (pesticides, growth regulators, fertilizers, etc), chemistry of plastics, petrochemicals, environmental chemistry and toxicology, etc.

With respect to second to fourth year curriculum, he maintained that the second year should be for the basics, third year for instrumentations and separation techniques, and fourth year for specialized analytical methods, procedures, techniques, etc, on the following disciplines: pollution, including heavy metals, food & food toxicants, pharmaceuticals, pesticides residues & formulations, petrochemicals, social poisons, QA/QC and a course covering some very important issues like the conventions, standardization, regulations & acts, Codex Alimentarius, accreditation.

East African Perspective-Prof Anthony Gachanja (Jomo Kenyatta University of Agriculture and Technology, Kenya) and Dr Jonas Mwatseteza (University of Malawi, Chancellor College)

Prof Gachanja outlined Analytical Chemistry curricula in the region including polytechnics and university degree programs. He mentioned that public universities offer the following; Chemistry degree program, Analytical Chemistry (with options), Post-graduate programs in Chemistry and post-graduate programs in Analytical Chemistry. He raised a question of whether the universities need the curricula, and expressed his view that curricula should be designed for the product to satisfy a market and that the market should be involved in design process of the curricula since it will use the product. He explained that most programs in the region are pirated, and with minimum change adopted by the relevant council, and that they originated from the University of East Africa, then Nairobi, UDSM and Makerere Universities.

He mentioned that theory is well covered in most cases and that students are eager to learn and most do very well, but that deficiencies such as lack of instrumentation and lack of qualified personnel in the field of Analytical Chemistry continue to pose a challenge. He mentioned that there are few PhD holders trained in the field, consequently other members with specialties in other fields handle the Analytical Chemistry units, with questionable results. Lack of proper support from university authorities, for instance in the purchase of instruments, is also problematic. Money may be available but the goodwill may be lacking. Lack of proper emphasis on newer analytical methods and techniques, e.g. packed column-CG vs capillary GC, microextraction methods, etc, is also another challenge that the region faces. The absence of professional bodies/societies in the field of Analytical Chemistry is seen as being detrimental in the marketing and progress in this field. An association such as Association of Analytical Chemists of Kenya would bring together practitioners in the academia and in the industry. Absence of local journals specifically dedicated to Analytical Chemistry papers. Lack of specialized analytical chemistry consumables such as 0.45 um filter papers in some laboratories, solid phase extraction cartridges, etc, is also seen by Prof Gachanja as being an impediment to the progress in the advancement research in this area. He believes that most

graduate theses that claim to be in the analytical chemistry field are actually analytical determinations with little on method development, optimizations and validations. Such would better fit in the environmental fields.

From this discussion he summarized the following as a way forward in the implementation of an Analytical Chemistry curricula in Africa; train more personnel in the field through centres of excellence, develop curricula through stakeholders forums, invest in analytical instrumentation, workshops for lecturers, form local professional associations to spearhead the emphasis in analytical chemistry, establish local/regional/African journals dedicated to analytical chemistry, and establish exchange programmes for students and staff within regional universities.

Dr Jonas Mwatseteza outlined the Government arrangements in Malawi with the Ministry of Education responsible for education in Universities and the recently established National Commission for Science and Technology (with a Division for Basic Sciences and Agriculture) responsible for the development of science in the country. He mentioned that public universities that offer chemistry in Malawi include; University of Malawi, Mzuzu University and several coming up (applied sciences), while private universities (approx 6) do not offer chemistry. The course structure includes; 4 year chemistry course at Chancellor College (2 semesters for analytical chemistry), 2 year chemistry course at polytechnic (laboratory technology diploma offered by apccem), 3 year chemistry courses at Mzuzu University (courses dominated by organic chemistry followed by physical and inorganic chemistry). Analytical chemistry topics at Chancellor College at third year are as follows; measurement and data analysis, good laboratory practice, material balance, classical methods of analysis, and introduction to analysis of real samples while fourth year includes electroanalytical techniques, atomic and molecular spectroscopy, chromatography and analysis of real samples.

Dr Mwatseteza identified the following institutional system constraints; limited capital investment, unrealistic recruitment policy, inappropriate funding allocation to science, out of phase government subvention and procurement procedures not in tandem with funding and availability of supplies. He also identified the following faculty constraints; inadequate numbers of faculty staff (one analytical chemist), inadequate technical staff, obsolete laboratory equipment and proportional low numbers of students graduating in Chemistry (minimum of 2 out of 4 courses at year 4). Beyond faculty constraints include; absence of career guidance to secondary school students, employers and departments not communicating adequately, inadequate placement opportunities for students during training, employers not forthcoming to invest in training and lack of appropriate financial reward for chemists. He also highlighted the following as the current state of affairs in the workplace; analytical chemistry in high demand, emphasis on laboratory technicians (diploma), technicians trained in chemistry related disciplines performing analytical chemistry tasks. He added that Chancellor College graduates are “expensive” to employ but are “better skilled” even though still struggling and there are industry complaints about the performance of analysts. He mentioned that service institutions tend to acquire state of the art analytical instrumentation that is rarely utilized which could be useful for research at universities.

He proposed the following for consideration; strengthen regional and international networking, use professional society platform to promote Analytical Chemistry in particular, institute Analytical Chemistry workshops at National and Regional Level, review curricula regularly, bring on board suppliers of equipment and chemicals, lobby stakeholders to reward chemists appropriately, and revive Chemistry Honours programme. He suggested the following curriculum review strategies; allocate more time for Analytical Chemistry in the curriculum, align curriculum with the region, emphasize on more instrumental practical sessions, and institute/encourage postgraduate programmes with strong taught aspects of Analytical Chemistry in the region (consider scholarships for students).

West African Perspective- Prof. Percy Onianwa (University of Ibadan, Nigeria)

Prof Onianwa expressed the importance of Analytical Chemistry in providing accurate chemical-related data/answer on what is present in a sample of matter (and how much is present) for sound decision making in various fields, e.g. industrial production, health management, trade/export, sports, environmental management, warfare, forensics, etc. The noted that the curriculum must therefore take cognisance of the subsequent application of whatever trainings are provided in Analytical Chemistry.

He explained that more than 100 public and private universities now exist in Nigeria and that almost all have Departments of Chemistry. Undergraduate programmes include BSc in: Pure Chemistry, Applied Chemistry, and Industrial Chemistry. No BSc (Analytical Chemistry) as a programme exists in Nigeria. At the University of Ibadan, Analytical Chemistry as a unit in the Department of Chemistry evolved from the Inorganic Unit only in the earlier 1980s, despite fact that Postgraduate Diploma in Analytical Chemistry existed since 1964 and an MSc (Anal. Chem.) programme existed since 1976. This trend is largely due to stereotyping among other chemists that analytical chemistry is only a tool of all other branches of chemistry, and not a whole branch by itself and that anyone can practice/teach chemical analysis. Prof Onianwa does not view the current BSc programme as being able to make the undergraduate students become core analytical professionals. The component of the programme at first year are as follows: no analytical chemistry courses, only physical, inorganic and organic courses taught to all science based disciplines, general chemistry practicals that include titrimetry. Second Year is as follows; courses on titrimetry, gravimetry, concentration units, analytical chemical arithmetic, basic sample preparation techniques and practicals in titrimetry & gravimetry hosted by inorganic group., and the third year includes courses on quantitative atomic and molecular spectrophotometry, separation methods, electroanalytical methods, introduction to IR, MS and NMR (hosted by organic group) and practicals on gravimetry, uv-visible spectrophotometry, etc, hosted by inorganic and physical groups. Fourth year includes; courses on analytical data management, quality assurance and analysis of real samples (foods, drugs, water, air, soils, etc). Practicals reserved for only the analytical chemistry group, involving titrimetry, gravimetry, spectrophotometry, separations, electroanalytical and real sample analysis. Many research projects involve analysis of real samples.

The Department of Chemistry at Ibadan University offers an MSc in Analytical Chemistry and an MSc in Environmental Chemistry which are run over three semesters (18 months) for each programme. MSc by course work which includes advanced lectures on; research methods, data management, QA/QC, titrimetry, gravimetry, reaction chemistry, electroanalytical methods (potentiometry, voltammetry, coulometry, amperometry, electrogravimetry, etc), quantitative spectrophotometry (AAS, AES, ICP, MAS, AFS, XRF, etc), separation methods (GC, GC-MS, ion exchange, HPLC, solvent extraction, ion chromatography, etc), radioanalytical methods (neutron activation, radioimmunoassay, etc), thermal methods, enzymatic methods, water analysis, air analysis, food analysis, drug analysis, analysis of miscellaneous organics & biological samples, and practicals as well as the required environmental chemistry courses. The programmes also include a 6-months research project.

Prof Onianwa identified the following shortcomings; advanced instrumental techniques not readily available for students' practicals due to large numbers, breakdowns, etc. In some universities (not Ibadan) Analytical Chemistry courses may be taught by non-experts (without MSc in Anal. Chem.). Some topics are not being taught currently, e.g, microscopy techniques. Electrochemistry and data management are still difficult courses for students according to Prof Onianwa. Teaching of hybrid methods (e.g. LC-MS, GC-MS, ICP-MS, etc) are sometimes

missed due to compartmentalisation and non-harmonisation of lectures. Some lecturers do not keep abreast of current trends and advancement in analytical methodologies. Some lecturers are not thorough/creative in teaching the courses allotted to them. He suggested the following as a way forward; minimum curriculum requirements need to be defined, but institutional peculiarities should determine sessional distributions. Specific pedagogic skills need to be developed and shared among teachers of identified difficult topics. An Africa-wide network needs to be developed to build on the gains of SEANAC, and propagate useful curriculum and practice related information. Institutions should be encouraged to employ only professional Analytical Chemists (min. MSc) in the teaching of Analytical Chemistry Courses. Books need to be written on several topics that are currently not sufficiently treated in available books, e.g. “general steps in chemical analysis” and “analytical chemical arithmetic”.

Mining sector perspective-Mr Sicelo Msada (Impala Platinum Ltd, South Africa)

Mr Msada defined Analytical Chemistry is a branch of chemistry that seeks to identify what is in a material and the amount, and that the information generated is used for quality control purposes and process control for their industry. He added that it provides data in support of other branches of chemistry and that it can be used to solve existing problems. He outlined the following sampling and sample preparation techniques being particularly important in the mining industry; grab sampling, composite sampling, acid digestion, fusion and pressure dissolution. The following metal determination techniques are also considered important for this type of industry; ICP-OES, ICP-MS, XRF/XRD, SEM, Optical Spark Emission/DC arc, AAS, UV/VIS, Fire Assay and LIMS. He also considers the following quality management standards as being crucial in their operations; ISO 9001 (planned job observation, internal quality audits and external audits), ISO GUIDE 17025 (round robins and turnaround times) and ISO 14001 (environmental audits, environmental risks and waste management). Safety considerations are also crucial for this industry and the OSH Act is the guide, and it involves regular inspections, quarterly competitions, meerkat audits and risk analysis.

Mr Msada identified the following challenges for the mining industry; call for higher precision and accuracy by customers, inability of the graduates to apply the theoretical knowledge acquired at higher institutions of learning, need for lower LODs and LOQs, costs of preventative maintenance contracts and hazardous chemicals used. He explained that they employ chemical analysts with Grade 12 (with a pass in Mathematics and Physical Science) and chemists with a general BSc degree or B Tech diploma and higher degrees.

Research perspective (CSIR, South Africa)-Mr Nial Harding

Mr Harding explained that CSIR consists of a number of business units, and that with the exception of some laboratories, analysts work in an “island”. The CSIR Analytical Chemistry Forum was therefore formed to provide a platform for discussion and development of Analytical Chemistry within CSIR, and amongst its roles is the development of a database containing information pertaining to human, instrumental and software resources available within CSIR, development of training and mentoring programs within CSIR, adoption of ISO 17025 as the quality standard throughout CSIR analytical laboratories and promotion of networking within and outside CSIR.

Mr Harding believes in the Dunning-Kruger effect which is concerned with cognitive bias, and he views the three areas which are crucial in building competence as knowledge, skills and attitude. He raises a question of how do we create a curriculum that keeps pace with developments in the analytical science field? He also views learning as a process whereby

knowledge is created through transformation of experience. Effective learning is both abstract and concrete, he says, and that concrete + abstract = higher-order of understanding. He believes that having an experience is not the same as learning from it and that action and thought have to be linked, and that this requires debriefing/reviewing/processing or mining to accomplish the learning process. He expressed that science is simply the method we use to try to postulate a minimum set of assumptions that can explain, through straightforward logical derivation, the existence of many phenomena of nature. On creating/expanding an existing science Eliyahu Goldratt states that "what is needed is the courage to face inconsistencies and to avoid running away from them just because that's the way it was always done. On the meaning of education Mr Harding sincerely believe that the only way we learn is through our deductive process and that presenting one with final conclusions is not a way that we learn. Our text books should not present us with a series of end results but rather a plot that enables the reader to go through the deduction process himself, he remarked, and that the following process should be adopted; ask a question, do background research, construct a hypothesis, test with experiment, analyze results & draw conclusions, re-examine the hypothesis if false results are obtained, report results when hypothesis is true.

Mr Harding suggests the following for a curriculum with a main focus on Analytical Sciences; Skoog & West provides a good starting point for fundamentals & instrumental techniques, emphasis on thinking skills (critical thinking - socratic approach, lateral thinking), working knowledge of inorganic, organic & physical chemistry and quality standards (ISO 17025 & GLP), concepts on validation, computer science (working knowledge of networking protocols, database design & management) and introduction to LIMS, purpose & function.

The role of science councils and voluntary associations- Dr Partricia Forbes (SACI ChromSA Division chairperson)

Dr Forbes explained that professional registration at Science councils, e.g. SACNASP (South African Council for Natural Scientific Professions, www.sacnasp.org.za) is an important career milestone for scientists and that it shows that one is a professional and that has the technical competence which is valued by industry. Professional registration identifies one as a highly skilled professional with technical knowledge and competence. Benefits of professional registration include; indicating that your competence and commitment to professionalism have been assessed by other natural science professionals, recognition that you have received education and training that meets standards for knowledge and experience, acknowledgement of professional standing by peers and colleagues, identifying one as having competences that employers value, higher earnings, better employment prospects and career mobility and access to a network of qualified professionals in one's area of expertise so as to keep abreast of the latest developments.

Some excerpts from the The Natural Scientific Professions Act, 2003 (Act No 27 of 2003) are as follows; only a registered person may practise in a consulting capacity. Categories include: Professional Natural Scientist – "Pr.Sci.Nat.", Candidate Natural Scientist - "Cand.Sci.Nat." and Certificated Natural Scientist – "Cert.Sci.Nat." A certificated natural scientist or candidate natural scientist – may only perform work in the natural scientific professions under the supervision and control of a professional natural scientist. A person who is not registered in terms of this Act, may not – perform any kind of work identified for any category of registered persons in terms of this section

She expressed that voluntary associations have a vital role to play in the development of (postgraduate) students, as well as in the continued education of working professionals in Analytical Chemistry. This is typically achieved by the organisation of events such as

conferences, student workshops, short courses and lecture series. She added that voluntary associations also serve as an important network for Analytical Chemists, and that numerous associations, institutes, societies and interest groups exist which relate to Analytical Chemistry, e.g. SEANAC, Divisions of SACI (Analytical, ChromSA, SAAMS, Electrochemistry, Thermochemistry, etc) and International bodies such as RSC, ACS, etc. She concluded that science councils and voluntary associations have an important role to play in the professional development of analytical chemists and in promoting the discipline and that it is important for both under- and postgraduate students to be made aware of the existence of such organisations and to be informed about what they can offer. She challenged these organisations to be flexible in meeting the needs of Analytical Chemists and their employers. She also expressed the importance of the links between science councils/voluntary associations, academia and industry, as being are vital in the advancement and marketing of Analytical Chemistry.

3. CHALLENGES OF ANALYTICAL CHEMISTRY AS A DISCIPLINE IN SCIENCE

Some of general challenges faced by analytical chemistry are as follows:

- Current teaching of analytical chemistry has no emphasis on quantitative aspects. Misconception that anyone can generate good data without any understanding of the theory underlying the technique.
- Stoichiometry in analytical chemistry is being less emphasized and in some cases disappearing.
- Some argue that analytical chemistry is not a science while it in fact is a discipline with its own terminologies.
- Students graduate with a four year degree without a clear understanding of what analytical chemistry is as a discipline in chemistry.
- Students graduate in analytical chemistry without having core competences of the theories, basic fundamentals underlying analytical chemistry such as mole concept, measurements etc.
- Limited time is given in teaching analytical chemistry in the four year general chemistry program compared to other disciplines.
- Components of analytical chemistry in the four year general chemistry program are not really identified as such. Some components like measurements are seen by students and even lecturers as belonging to mathematics and easily forgotten along the way.
- There is no clear introduction of analytical chemistry in the first year general chemistry program. This is contrary to other disciplines such as organic chemistry where such component stand out very clearly.
- Too many experiments in analytical chemistry that deal with titrations at first and second years. What experiments are needed to replace the titrations?
- No proper analytical instrumentation in some labs that can support the theory in some universities. Lack of qualified manpower with technical expertise.
- Lack of specialized analytical chemistry consumables in some regions of Africa.
- Lack of proper support from university authorities with regards capacity building and infrastructure.
- Improperly trained lecturers in some components of analytical chemistry such as electrochemistry.
- Several topics that are currently not sufficiently treated in available books.
- Lack of workshops in analytical chemistry.

- Absence of professional bodies/societies in the field of Analytical Chemistry around Africa.
- Lack of local journals addressing analytical chemistry.

4. FOUR YEAR ANALYTICAL CHEMISTRY CURRICULA WITHIN THE GENERAL SCIENCE PROGRAM

From the above challenges facing analytical chemistry curricula, the components of analytical chemistry that should form a four year general chemistry degree are outlined. It is acknowledged that most core analytical chemistry subjects are there in the current programmes but perhaps needs repackaging when teaching them. Repackaging should involve making sure that analytical chemistry comes out clearly that it is a discipline of its own within Chemistry and that is relevant to other disciplines.

Year I

- The components of analytical chemistry in current general chemistry program need to be repacked when teaching so that where possible they are linked to the discipline of analytical chemistry. This is important as students should be able to link these components to others in the coming years as they move along. It is important that these components are well taught and understood by the students. Some of these components include: matter and measurements, stoichiometry, aqueous reactions and solution stoichiometry, acid base titrations, and introduction to electrochemistry. Practicals in electrochemistry should also be included.
- Reducing the number of titrations experiments where possible and introduce others that illustrate concepts of analytical chemistry at no additional costs (e.g. paper chromatography). Titrations could be limited to acid base titrations and cover important aspects such as strong acid base titrations, strong acid/base vs weak base/acid, concepts of standardization and standard solutions. Real life applications of acid base theory should be included in the practicals.
- Concepts relating to measurements such as uncertainty, significant figures, precision and accuracy should be highlighted when dealing with titrimetric analysis.
- Aspects of water chemistry highlighted in some chapters especially those that deal with pH of solutions and solution equilibria.
- Linkage should be made where possible when teaching components of analytical chemistry at year 1 with everyday life and analytical chemistry as a discipline.
- Basic introduction to GLP standards.

Year II

The following are proposed for second year teaching. It should be pointed that here, some aspects of the components such as atomic absorption spectrometry, photometry, UV/VIS could also be moved to year III as is the current practice in some Universities. In fact, courses could be interchanged between the second and third year depending on the department curriculum review. What is important is that the competence of the students in these areas is achieved.

- Statistical analysis and computing for analytical chemistry

- Sample handling-an introduction that includes sampling and sample preparation (eg, solvent extraction)
- Classical methods of analysis (e.g. gravimetric, titrations, complexation, etc).
- Atomic spectroscopy theory, principles and instrumentation (FES, AAS, ICP, MS).
- Molecular spectroscopy theory, principles and instrumentation (UV/Vis, Fluorescence, IR).
- Electroanalytical (introduction to electronanalytical, current & concentration relationship, pH, electrodes and potentiometry)
- Modifications of experiments to minimise titrations ones and introduce new ones that introduces other concepts of analytical chemistry and those that illustrate real life examples.
- Introduction to quality management standards.

Year III

The following are proposed for third year teaching.

- Sample preparation- types of samples, analytes, and sample handling techniques.
- Introduction to theory of separation science. Gas chromatography principles, instrumentation and detectors. Liquid chromatography principles, instrumentation and detectors. Ion chromatography principles, instrumentation and detectors.
- Introduction to capillary electrophoresis, theory, instrumentation and detection.
- Electrochemistry theory and application (e.g. practicals on ion selective electrode applications, voltammetry, stripping voltammetry, sensors, etc)
- Introduction to NMR.
- Hands on experience on instrumental methods should be a requirement (e.g. software, troubleshooting, etc).

Year IV

The following are proposed for third year teaching. The actual number of topics that can be given is left to individual departments to decide based on the expertise and needs of the country.

- Mass spectrometry-detailed theory, instrumentation and applications, hands on practicals where possible
- Thermal analysis-theory and applications
- XRD/XF theory and applications
- NMR theory and applications
- Chemometric
- Special Instrumental techniques (SEM, TEM, BET, XPS)
- Application of Analytical Techniques (e.g. Pharmaceuticals, Environmental, Biochemical, Foods, Pesticides, Atmospheric, Climate, etc)
- Sample preparation covering different analytes and various techniques. Theory and principles of sample preparation techniques included.
- Method validation
- Nuclear techniques
- Mini project in analytical chemistry

Level V (M.Sc)

This programme should be left to Departments and the courses below can be offered depending upon the research activities of the department. Most MSc courses are aimed at preparing postgraduate students to fulfil their research obligations. Some postgraduate students can take some honours courses to bridge some gaps when necessary and administration of such can be worked out by the department. Other courses in level IV can also fall under level V depending on what is covered and the structure of a program. Possible courses that can be included in level V are:

- Advanced instrumental analysis
- Advanced sample preparation including trends
- Hyphenated techniques

5. SHORT COURSES IN ANALYTICAL CHEMISTRY

Courses in analytical chemistry should be offered to bridge the gaps in people already in practise and lecturers who are inadequately trained. These courses should include basic theory and practical aspects of analytical chemistry. The levels of these courses could vary but mostly may start with covering year III and year IV topics as needed. Such courses can be advertised on SEANAC and SACI websites where each country can assess the website. Experts in various countries can offer such courses so that use of the national expertise is encouraged.

6. GENERAL

Various issues around the marketing of analytical chemistry are given below, and could help to influence curricula and the advancement of Analytical Chemistry:

- Presentations should be offered to company practitioners of analytical chemistry
- Career paths should be offered to undergraduates especially at year I.
- Writing of text book or manuals for general chemistry or analytical chemistry so that all disciplines of chemistry are equally presented.
- Workshops on analytical chemistry should be encouraged.
- Exchange of staff to teach analytical chemistry within various Universities depending of available expertise.

7. WAY FORWARD

This document provides a platform for the review of Analytical Chemistry Curricula by Departments and Schools of Chemistry. It should be noted that most Universities from Africa offer 4 or 5 year programmes, and that harmonization of curricula should take this into account. Industry gaps from other African countries should also be identified and the harmonization implemented accordingly. Human resources, instrumentation and facilities are crucial in the implementation of this proposed curriculum; however the staff exchange and training programmes can assist with the former but the latter two require funding which institutions are encouraged to support. The SEANAC/SACI forum should be a platform in foregrounding the benchmark of the Analytical Chemistry Qualification.