# Enhancing Chlorination Fundamentals for Water Treatment Technology IV course Using on-line multi-media

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**ABSTRACT**

The current paper demonstrates the use of on-line multi-media, i.e. "chlorination of natural waters" and "dissociation of weak acids" from Merlot database, to enhance teaching and learning for Water Treatment Technology IV course material. This database focuses on fundamental concepts for chlorination as one of the most prominent disinfection treatment technology processes in the world and in South Africa. The course is part of the curriculum for the bachelor of technology degree in civil engineering, water specialisation at the University of South Africa (Unisa). The evaluation of these Merlot learning objects shows that accessibility, interaction usability, learning goal alignment, adaptation and motivation may be achieved during learning.

**Keywords**: Multimedia, e-learning, chlorination, acid, dissociation

## 1. INTRODUCTION

The choice of on-line material during design process can be approached from learning theory [20] and depends on the type of students involved in teaching and learning. Web enabled multimedia have benefits for teaching and learning [6], [9]. The purpose of this preliminary study is not to debate around the effectiveness of multi-media [3], [4], [5], [8]. Nonetheless multi-media present some advantages for learners who would appreciate pedagogical approaches supported with visual representation in enhancing specific concepts of the course. The current study uses the most popular on-line free available educational resources, i.e. Merlot multi-media to enhance the understanding of fundamental concepts for water treatment processes, in particular chlorination as part of Water Treatment Technology IV course. Chlorination is the mostly used disinfection water treatment technique in the world and in South Africa and is used in the form of compressed gas under pressure which is dissolved in water at the point of application or solutions of hypochlorite.

Water Treatment Technology IV course is a year course (that covers theory and project components) and is prescribed in the water specialisation of the curriculum of bachelor of technology degree in civil engineering (BTechCivil), at the University of South Africa (Unisa). The curriculum is standardised across all universities of technology (UoT) in South Africa. The current teaching and learning happens in asynchronous mode, for the majority of courses at Unisa mode. This mode of learning offers some advantages, i.e. learner can study at his own pace, anytime and anywhere. However, the course content for Water Treatment Technology IV requires prior knowledge in general chemistry, which is unfortunately not covered in the previous years of the National Diploma Civil Engineering (NDECV). Hence, this situation leads to a certain level of difficulty that learners battle with the chemistry involved in the different treatment technology processes of the course. Hence, on-line multimedia i.e. "chlorination of natural waters" coupled with "behavior of weak acids" [1] are used for the purpose of this study and the cost effectiveness of these free on-line materials is an advantage [19]. Similarly to Hydrology IV [6], the course material for Water Treatment Technology IV is uploaded in pdf format on the learning management system (LMS) called myUnisa. The use of text, figures and tables alone are necessary but not sufficient for enhancing ultimately teaching and learning. Learners should be exposed to a variety of multi-media skills [13]. For this reason, the aforementioned Merlot multimedia were used to give a good foundation for water technology treatment processes, particularly the foundation focuses on chlorination as one of the disinfection techniques. It is strongly motivated in this study to explain the fundamentals of chlorination by using interactive educational resources such as Merlot. The tuition policy at Unisa supports the use of web enabled resources for on-line teaching and learning. "Chlorination of natural waters" multimedia explains the chlorination process in very simple terms. Then, the dissociation and the formation of hypochlorous acid are carried out under the influence of different parameters: temperature, salinity and pH of natural waters. In addition, the "behavior of weak acids" multimedia is used to establish the comparison between dissociation capabilities between hypochlorous acid and other weak acids. In what follows, "student" and "learner" will be used interchangeably.

## 2. OVERVIEW ON CHLORINATION IN WATER TREATMENT TECHNOLOGY IV COURSE

For water treatment, chlorination is one of the popular disinfection techniques. Chlorination is conducted after most treatment processes have been carried out, e.g. coagulation and flocculation, clarification, filtration and membrane, etc. Chlorination is carried out to clear pathogens and bacteria that could be harmful to human health before it is disposed for drinking. The addition of chlorine in water yields to two main chemical reactions:

$$Cl_2 + H_2O \leftrightarrow HClO + H^+ + Cl^- \quad (1)$$

$$HClO \leftrightarrow H^+ + OCl^- \quad (2)$$

The first reaction is the formation of hypochlorous acid (HClO) and the release of ions $H^+ + Cl^-$. The second reaction is the dissociation of the acid into ions $H^+ + OCl^-$. The presence of ions $H^+$ defines the degree of acidity of the solution. Hence, these two reactions depend on the pH of water. The pH is

critical in affecting the formation or the dissociation of hypochlorous acid (HClO). This is a weak acid characterized by a very low dissociation constant of the order of $10^{-8}$.

In practice, chlorination may be done in the following three ways [7]:

*Marginal chlorination*: sufficient chlorine is added to water to give the required free chlorine concentration to ensure that pathogenic species have been killed and water is of high quality.

*Breakpoint chlorination*: chlorine is added to water in such a way all the ammonia nitrogen present in the water has been rapidly oxidized and leaves an adequate amount of free residual chlorine to ensure that water is not re-infected from the plant where chlorination occurs to the point of use.

*Superchlorination and dechlorination*: It can be used in case of poor water quality or having a significant bacterial load. A large dose of chlorine is added to accelerate disinfection process well beyond the breakpoint and this is followed by reduction of excess free chlorine residual. The excess chlorine is decreased by the application of a dechlorinating agent (e.g. sulphur compounds or activated carbon).

The syllabus/curriculum content for water treatment technology IV covers the following study units among others: Introduction to Water Quality and the Legislative Framework; Overview of Water Treatment Processes and Process Design; Pre-treatment; Coagulation and flocculation; Clarification; Filtration and Membrane processes; Disinfection; other processes and finally operational imperatives. Learners' needs should be catered for through course curriculum design and development [11], specifically in water specialization. In addition to the above-mentioned study units, the course has a project component that focuses on the student visit to a typical water treatment facility. For more details about the content and learning objectives of each study unit for the course, the reader can be referred to study guide [7]. Learning objectives of disinfection study unit where chlorination is covered are achieved in part through texts, figures and tables in the current water treatment technology IV course and no other multi-media are used. Hence in this study, it is an opportunity to use free web multi-media such as Merlot to enhance the understanding of hypochlorous acid formation and its dissociation during chlorination.

## 3. OVERVIEW ON CHLORINATION OF NATURAL WATERS MULTIMEDIA

Merlot multimedia are presented in a form of graphical user interface (GUI), very interactive and self explanatory [1]. It starts with an introductory sheet giving the above-mentioned chemical reactions (1) and (2) that underline chlorination process (Figure 1). The second sheet is the dissociation of the hypochlorous acid for different parameters, i.e. temperatures, salinity and the initial acid concentration (Figure 2). The distribution of these components/species is displayed in the third screen through a tracer. This screen depicts the influence of temperature, salinity and pH (acidity) on the distribution of HOCl and $OCl^-$ concentrations (Figure 3). The introduction of the multimedia is presented in a form of a text but does not enable the user/learner to enter anything. Nonetheless, the second sheet is more interactive and enables the leaner to understand the dissociation of a weak acid such as hypochlorous acid. The second sheet enables the learner to vary parameters just by a simple click or drag and the learner can follow the changes in percentages or concentrations of chemical species during the decomposition of hypochlorous acid. Internet connectivity is only required for the first time in accessing the Merlot database [1], which are basically open educational resources (OERs). OERs are regarded as potential resources for education [12], [14]. Unlike in the case of Probability Calculator (PC) multi-media material [6], the interactive excel spreadsheets for general chemistry [1] can be downloaded and used off-line. It can be as well uploaded on myUnisa for use by students.

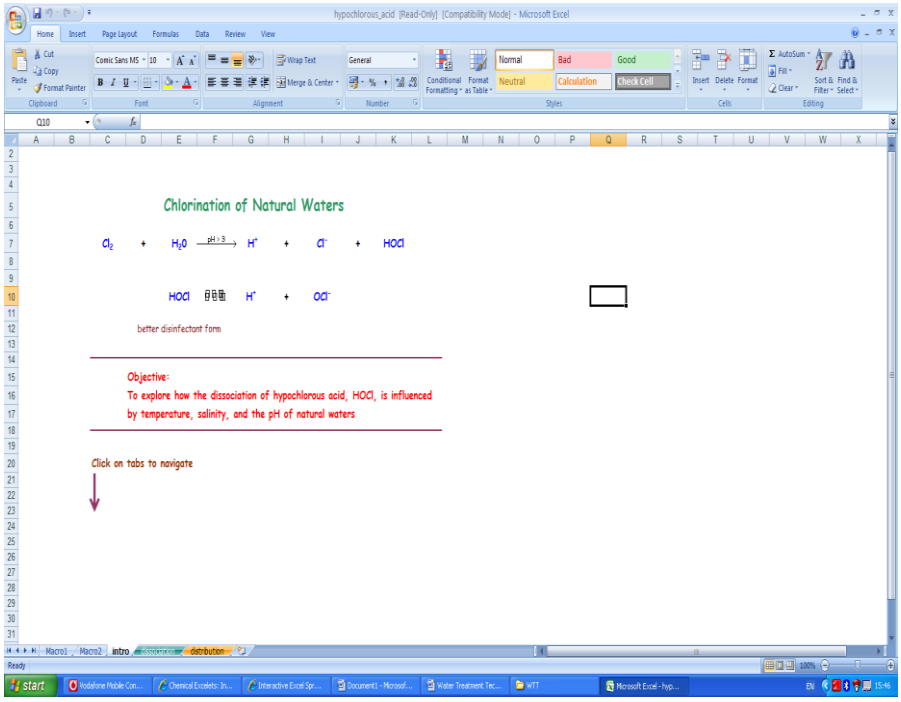


Figure 1. Summary of chemical reactions in chlorination of natural waters

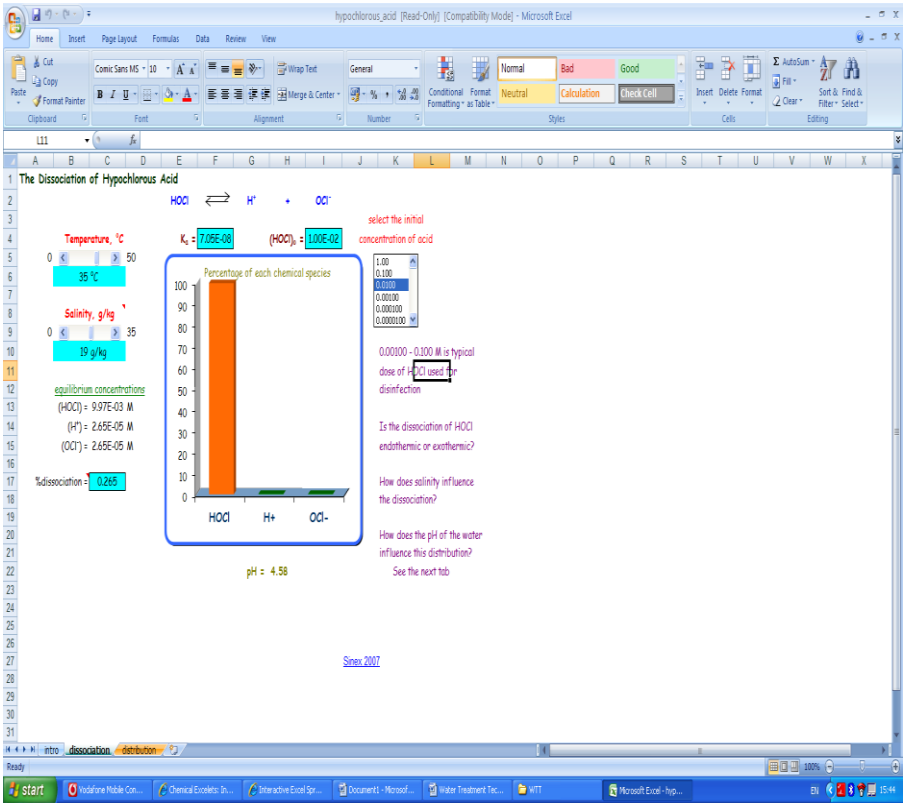


Figure 2. Sheet depicting the dissociation of hypochlorous acid

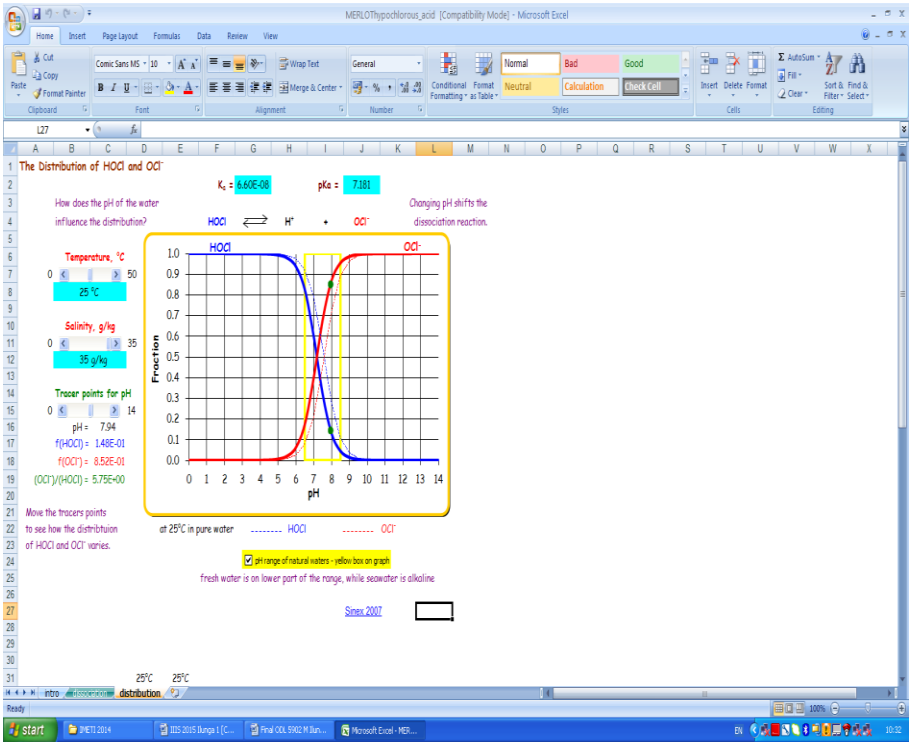


Figure 3. Distribution of HOCl and $OCl^-$ concentrations for different parameters: temperature, salinity and pH.

## 4. METHODS & MATERIALS

### Materials

The material used in this study is Water Treatment Technology IV course in the form of text, figures and Tables as well as materials from Merlot database as explained previously.

### Instructional design methods and multimedia evaluation

Like in the case of Hydrology IV [6], the Dick and Carey's system instructional design method was used to enhance chlorination in Water Treatment Technology IV. This model is articulated essentially on ten interlinked parts, i.e. identify instructional goals, analyze learners and contexts, conduct instructional analysis, write performance objectives, develop assessment instruments, develop instructional strategies, develop and select instructional material, design and conducting formative evaluations, revise instructions, design and conduct summative evaluations [15]. In order to enhance fundamentals for chlorination technique as approached in Water Treatment Technology IV course, only relevant parts from Dick and Carey's system model were applied. Hence, the identification of appropriate multi-media for the purpose of enhancing fundamentals for chlorination water treatment process in Water Treatment Technology IV will be conducted. Then analysis of learners and contexts will be carried out, e.g. pre-requisites for Water Treatment Technology IV should be identified as well as the level of difficulty in understanding chlorination process by learners. Instructional analysis will be conducted e.g. skills and knowledge acquired by using the current figures, tables and text in this study unit may not be sufficient, hence other multimedia may be seen as added value for teaching and learning. The performance objectives will be assessed e.g. learners should be able to understand the dissociation process and formation of different compounds/species involved in chlorination. The development of instructional strategies should be conducted e.g. the use of Merlot multimedia may enhance teaching and learning to achieve learning objectives of the study unit. The development and selection of instructional material is very important e.g. the use of appropriate multimedia should be added strategically to Water Treatment Technology IV course material for further understanding of chlorination in practice. "Decomposition of weak acids" multimedia was added just to compare the degree of dissociation between hypochlorus acid and any other weak acid, e.g. acetic acids, etc.

Chlorination may contribute just to a portion of formative assessments as well as summative assessment. The combination of all study units normally should contribute to summative assessment, which is a written end of the year examination.

### Multimedia evaluation

The following criteria: content quality, accessibility, interaction usability, learning goal alignment, feedback and adaptation, motivation, presentation design, accessibility reusability and standards compliance are widely used in evaluating learning objects, e.g. [10], [6]. Only those criteria applied to the current study were used (see Table 1 in the next section). A scale of 5 digits (e.g. from low to high), are normally used for each criterion [10]. A holistic evaluation of learning materials [17]

was not necessary since LORI (Learning Object Review Instrument) was found suitable for this study. The use of multi-media should normally be combined with a sound pedagogy for effective teaching and learning. However, pedagogical aspects are not the subject of this preliminary study.
The author of the paper liaised with educational consultants from the directorate of curriculum and learning development (DCLD) for multimedia preliminary evaluation before any implementation of "chlorination of natural waters" and "decomposition of weak acids" Merlot multi-media for teaching and learning.

## 5. APPLICATION AND RESULTS

### Instructional design and multimedia evaluation

According to instructional approach and multimedia choice for Water treatment Technology IV course laid previously, the following steps were approached and summarized as follows:

1. Identify instructional goals. MERLOT objects, specifically "chlorination of natural waters" and "dissociation of weak acids" were identified to enhance learning for chlorination fundamentals in Water Treatment Technology IV. These objects are user-friendly. They are not only freely available on the Internet, but they can be downloaded and used off-line.
2. Learners in BTechCivil Water specialization, experience difficulties for understanding of chlorination chemical reactions since they don't have any general chemistry pre-requisite in the previous years of study, i.e. National Diploma. Hence, learners' contexts were identified.
3. When conducting an instructional analysis, relying only on text based material, tables and figures in Water Treatment Technology course IV; in particular chlorination process may not be effective for teaching and learning. Therefore, the use of additional web based multimedia was explored to enhance teaching and learning for chlorination as a disinfection technique.
4. A team approach is required for on-line free available resources such as "chlorination of natural waters" and "dissociation of weak acids" during course development.
5. Specific learning objectives related to chlorination were enhanced and achieved through the use of web based multimedia, in addition to the current course material.
6. MERLOT objects were used in conjunction with the current Water Treatment Technology IV material. This is seen as an enabling element for learners' readiness in both formative assessment and summative assessment.

Instructional development that focuses on the use of multimedia was carried out using only the above-mentioned six steps [6]. MERLOT multimedia were found very interactive objects enhancing teaching and learning. Referring to Figure 1, the short description of chlorination is explained clearly through chemical reactions (1) and (2). Learners can read the pH of the formation of hypochlorous acid. However, this first sheet is not enabled with a click. From Figure 2, users/learners understand better the dissociation of the acid into different species at different temperatures, salinity and initial concentration of the acid. It is possible to navigate between 0 and 50 degrees Celsius by just clicking and dragging the mouse. In this case, the user easily drags the cursor and observes that the acid dissociation constant increases from $1.4*10^{-8}$ to $4.61*10^{-8}$ and the pH decreases from the 4.43 to 4.17. Figure 3 shows that the pH influences the distribution of HOCl and $OCl^-$ for different temperatures and values of salinity. For example for pH = 8.18 and zero salinity, the user/learner may navigates between 0 and 50 degrees Celcius. In thi case, the dissociation constant varies between $1.36 *10^{-8}$ and $4.61*10^{-8}$. The fraction for HOCl decreases from 0.33 to 0.11, while the fraction for $OCl^-$ increases from 0.7 and 0.9. The user does not have to know the computations behind these results but to understand conditions that favor the formation and dissociation of hypochlorous acid. Figure 4 shows an example of weak acid dissociation. For the same initial concentration of 0.01 Molar, the constant of dissociation can be derived at equilibrium of the chemical reactions occurring in chlorination. Comparing Figure 4 and Figure 5, hypochlorous acid has a much lower % of dissociation, 0.173 than that chlorous acid for instance.

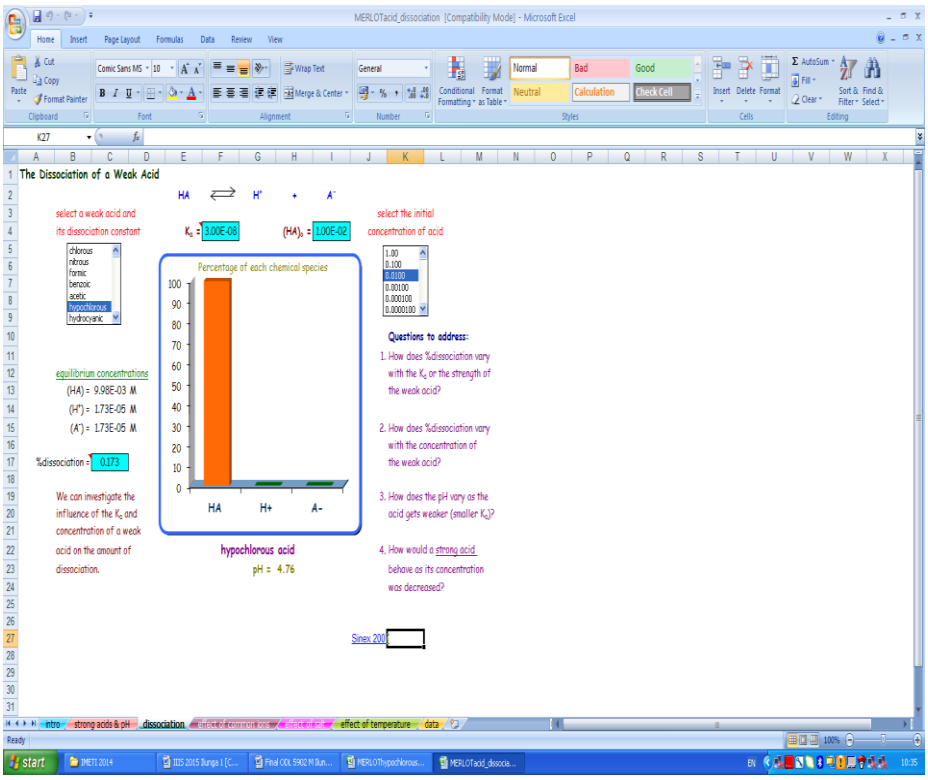


Figure 4. Percentage of dissociation and initial concentration for the hypochlorous acid

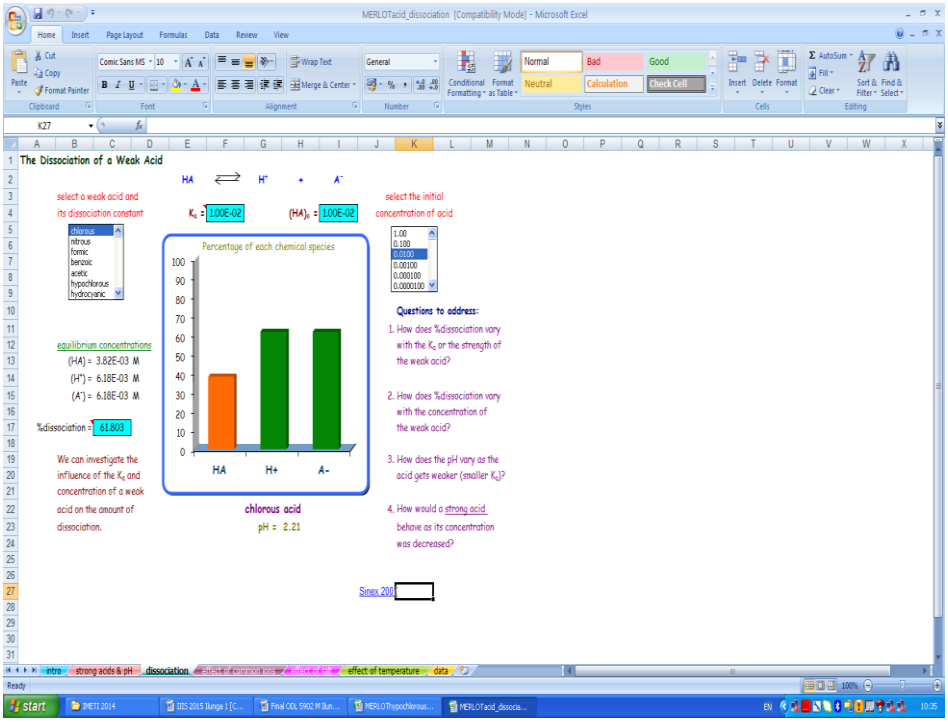


Figure 5. Percentage of dissociation, initial concentration for the chlorous acid

"Chlorination of natural waters" and "dissociation of weak acids" do not give the principle of calculation of pH, however the course lecturer could simply explain the concept to learner, as the negative of logarithm of concentration of ions $H^+$ in a particular solution. Hence, the explanation can be posted on myUnisa. These multimedia do not give as well the definition of constant of dissociation of a chemical reaction. This could be expressed as the ratio between product of concentrations of species at the right hand side of a chemical reaction and the product of concentrations of species at the left hand side of the same chemical reaction. Nonetheless, multimedia are user-friendly; free available from the Internet and can be used off line and linked to Water Treatment Technology IV course material; via LMS myUnisa.

Quality e-learning will need to be assured for successful learning [18], hence multimedia should be used based on sound pedagogical principles that align with learning objectives of the study unit. Effective technology should be coupled with quality teaching and learning and course planning [2].

**Multimedia evaluation**

This section is mainly based on LORI as outlined previously and adapted in Table 1. The scale 1 to 5 is varying from Low to High. The scoring is done as follows: 1: X; 2: XX; 3: XXX; 4: XXXX; 5: XXXXX. Previously adapted LORI approach have been carried out [6] , [10], [16].

Table 1. Multimedia evaluation in a form scoring sheet as adapted from [11].

| **Evaluation Criteria** | Chlorination of natural water | Dissociation of weak acids |
|---|---|---|
| **Content Quality**: Veracity, accuracy, balanced presentation and appropriate level of detail | XXXX | XXXX |
| **Learning Goal Alignment:** Among goals, activities, assessments, and learner characteristics | XXXX | XXXX |
| **Motivation:** Motivate and interest learners | XXXX | XXXX |
| **Presentation Design:** Visual and auditory information for enhanced learning and efficient mental processing | XXXX | XXXX |
| **Interaction Usability:** Ease of navigation, predictability of the user interface. | XXXX | XXX |
| **Accessibility:** Design of controls and presentation formats to accommodate disabled and mobile learners | XXX | XXX |
| **Reusability:** Use in varying learning contexts and learner backgrounds | XXX | XXX |

For the use of web mutli-media, the overall score of the criteria in Table 1 is fairly good. The content quality of the Merlot multimedia was shown to be relevant and was proven to add value to chlorination. In this way, the specific objectives related to chlorination could be enhanced and could satisfy learning alignment goal. These multimedia could be of interest and motivate the user in the understanding chlorination process.

In terms of presentation design, the visual information for MERLOT multimedia stimulates learning and teaching. "Chlorination of natural waters" and "dissociation of weak acids" focus essentially on visual learning. Learners may enrich experiential learning for further practical implications of chlorination. These multimedia do not require a high level of understanding of general chemistry, hence all types of learners, i.e. from the average learners to the smartest are accommodated.

Self-learning and independence is encouraged in the use of these multimedia, which are proven to be very interactive. As noticed in a similar study [7], these multimedia, on their own do not stimulate knowledge construction since the range of values for different parameters are already prescribed. Users just click and drag from prescribed values in the multimedia. Merlot multimedia are suitable for behaviourist learning and will be also helpful learners without any prior knowledge in general chemistry, i.e. learners at BTechCivil.

## 6.CONCLUSION

"Chlorination of natural waters" and "dissociation of weak acids" multimedia as part of MERLOT objects are essentially based on visualisation and were found to be valuable tools to enhance fundamentals of chlorination for teaching and learning,

specifically for Water Treatment Technology IV. Dick and Carey System Model for course instructional design and LORI multimedia evaluation approach were explored. LORI criteria for evaluation were satisfied and the multimedia were found interactive, accessible and user friendly for enhancing chlorination process. They were found suitable for learners who don't have enough general chemistry background. However, they are not recommended for constructivist learning.

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