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Research Article

Development of Teaching Materials and Concept Maps About the Relationship Between Sustainability and Chitosan for Water Treatment: Qualitative Content Analysis

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Abstract.
Chitosan is formed by deacetylation of chitin using strong alkali at high temperatures. The content of the active amine groups in chitosan is widely used as an alternative natural coagulant that is environmentally friendly. So, it can be included in learning materials about the concept of sustainability. This study aimed to produce concept maps and Teaching Learning Sequences (TLS) based on scientists' conceptions of sustainability on the topic of water treatment using natural coagulants. The method used in this research was qualitative content analysis. The research instruments included content analysis formats and sustainability aspects. The content analysis process included literature collection, descriptive analysis, category selection, and material evaluation with didactic aspects. This research produced concept maps and TLS that described the relationship between water treatment using natural coagulants and colloid content. Additionally, TLS related to sustainability education in the form of learning about water treatment using natural coagulants from chitosan was also developed. The concept map and TLS that have been compiled show the relationship between mapping aspects of scientific literacy and environmentally friendly water treatment using natural coagulants. The research results can be used as a basis for developing teaching materials and didactic designs.

Keywords: concept maps, sustainability, chitosan

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1. INTRODUCTION

Education for Sustainable Development is a learning process or it can also be said to be an approach to those based on lofty ideals and principles based on sustainability by focusing attention on all levels and types of learning to provide quality education and improve sustainable human development [1]. This concept focuses on how to meet the needs of life without sacrificing future generations in meeting their own needs today. The birth of this concept was triggered because the environmental conditions are

getting worse every day [2]. The implementation of ESD is carried out through various learning strategies, namely integrated in subjects, stand-alone (monolithic) subjects, local content, and extracurricular activities/self-development programs in schools, as well as habituation through the implementation of the school's mission vision, including the implementation of school regulations [3]. But in the learning process, there are still many who don't understand the concept of ESD, even though ESD itself is a learning process based on lofty ideals and sustainability principles. Therefore, there needs to be an academic follow-up so that the ESD can be implemented into the learning process in each educational unit, one way is to prepare educators who will implement this ESD concept in schools later [1].

Chemical learning has a very important role as a media for the implementation of learning for sustainable development [4]. Chemical learning, especially environmental chemistry is one of the study programs that must take a role to improve knowledge insights, change attitudes and train students to have environmental awareness. The concepts in chemical learning are very closely related to the environment so that they can provoke creativity and innovation in students in order to use chemical concepts to solve problems that occur around their environment [5]. One of the problems and issues in the real world attracting attention today is environmental pollution, especially in waters caused by the discharge of waste into the waters [6]. From this, students are required to overcome this phenomenon by contributing to the environment in solving the problem of water pollution through water treatment using several methods, including through coagulation methods [7]. Currently, the coagulation method using natural coagulants is attracting attention because it is considered more environmentally friendly and its raw materials are easily obtained [8]. Natural coagulants that are often used one of them is chitosan. Chitosan is an amino polysaccharide obtained from the chitin deacetylation process. The main sources of chitosan are organisms that live in seawater such as shrimp, crabs, and lobster shells. Chitosan is made through the process of preparation, deproteinization, demineralization, and deacetylation. The free amine group in chitosan makes chitosan more active and polycationic. These properties can be utilized as coagulants in the treatment of industrial liquid waste [9]. Other advantages of coagulants are non-toxic, harmless to human health, linear cationic polymers with high molecular weight and biodegradable ability. This is what causes chitosan to be widely utilized as one of the natural coagulants alternatives that are environmentally friendly, so it can be integrated into learning about the concept of sustainability [10].

Water treatment using this natural coagulant can be integrated with the teaching and learning process with the concept of sustainability. Implementation of topics such as

water treatment using natural coagulants in everyday life can help address environmental problems. This concept can be integrated in learning through the design of learning stages such as concept maps and TLS (Teaching Learning Sequences) from results that are in accordance with sustainability aspects. Concept map is a strategy that can be used by teachers / lecturers to guide students in compiling concepts that have been learned so that they can be seen the relationship with each other [11]. Concept maps can also help students to learn more easily and connect what they already know with what they are about to learn [12]. With the concept map, the material to be studied is more clear and practical [13]. In this study, the concept map acts as an initial picture of the interrelationship of concepts to be developed in TLS. TLS is a term that can describe a way to sort the stages of teaching and learning activities [14]. Things that exist in TLS include teaching and learning activities that have been tailored to the needs of students. Therefore, TLS is very important to be made so that researchers can know the order of teaching stages that are most appropriate for students based on student needs. Based on the description, the study aims to obtain a concept map and TLS from scientists' conceptions of the topic of wastewater treatment using natural coagulants.

2. RESEARCH METHOD

The method in this study is Qualitative Content Analysis / QCA [15], with the type of literature analysis [16]. The research flow scheme can be seen in Fig 1.

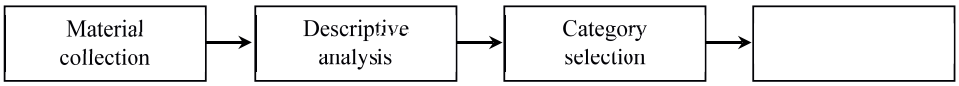

Figure 1: Qualitative content analysis stages.

The first stage is Material Collection, The collection of subject matter was conducted by qualitative content analysis of textbooks, monographs, review articles and research articles on the related topic. The instrument of this research is content analysis formats and sustainability aspects in the form of a table that includes the title, author, year of publication and code. The second stage is the Descriptive Analysis stage, which is the activity of describing the content from the sources that have been collected. The instrument is presented in the form of a table containing the contents and the results of the content analysis whose description is accompanied by coding from the source. The third stage is the Category Selection stage, which is the activity of structuring the results of content analysis. At this stage there are activities to incorporate pedagogical and didactic aspects into the content [5]. After that, the research ends with the Material

Evaluation stage, which is an activity to review the material from the beginning to the end and describe it into a structured concept map and TLS. A more detailed research flow scheme regarding the third and fourth stages can be seen in Fig 2.

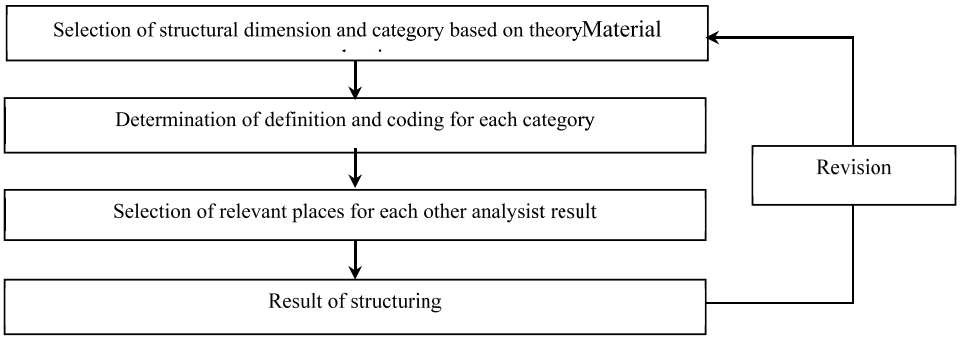

Figure 2: Structuring process of content analysis result [15].

3. RESULTS AND DISCUSSION

3.1. Description of Research Result Data

The first stage carried out is material collection. The sources used in the material collection process were textbooks, monographs, review articles and research articles. These sources are used as reference material in preparing content analysis. The sources used in content analysis are shown in Table 1.

3.2. Descriptive Analysis

The second stage is descriptive analysis, at this stage the sources that have been collected in the first stage are then analyzed and described. The results of the descriptive analysis are in Table 2. Table 2 describes the results of the analysis that has been carried out from several sources.

3.3. Category Collection

The third step in qualitative content analysis is category selection. Based on the findings in the previous stage, the results of the content analysis need to be structured. The goal is to see the pattern of relationships and interactions of each component involved. From some literature, obtained concepts related to chitosan as coagulants. These concepts are arranged in the form of visualization that is common in the world of education,

TABLE 1: The sources of material analyzed.

Author	Tittle	Year	Code
Zeyneb Kılıç [17]	Water Pollution: Causes, Negative Effects and Prevention Methods	2021	A
Wei Lun Ang, *et al* [7]	State Of The Art And Sustainability Of Natural Coagulants In Water And Wastewater Treatment	2021	B
Nayla Hassan Omer [18]	Water Quality Parameters	2019	C
Yongjun Sun, *et al* [19]	Evaluation And Optimization Of Enhanced Coagulation Process	2020	D
Dayarathne, *et al* [20]	Removal Of Natural Organic Matter From Source Water: Review On Coagulants, Dual Coagulation, Alternative Coagulants, And Mechanisms	2021	E
John Bratby [21]	Coagulation And Flocculation With An Emphasis On Water And Wastewater Treatment	2016	F
Ang, *et al* [22]	Chitosan As Natural Coagulant In Hybrid Coagulation-Nanofiltration Membrane Process For Water Treatment	2016	G
Marina Šciban, *et al* [23]	Removal Of Water Turbidity By Natural Coagulants Obtained From Chestnut And Acorn	2009	H
Djamel Ghernaout [24]	Water Treatment Coagulation : Dares And Trends	2020	I
Meysam Mohammad Momeni, *et al* [10]	Using Chitosan/CHPATC As Coagulant To Remove Color And Turbidity Of Industrial Wastewater: Optimization Through RSM Design	2018	K
Hossam Altaher [25]	The Use Of Chitosan As A Coagulant In The Pre-Treatment Of Turbid Sea Water	2012	L
Benedict, *et al* [26]	Eco-Friendly Approaches To Aquaculture Wastewater Treatment: Assessment Of Natural Coagulants Vis-A-Vis Chitosan	2021	M

namely concept maps. The use of concept maps aims to see the relationship between a concept and other concepts. Forms of visualization such as using a concept map are a useful starting point for considering the existence of systems thinking (Aubrecht, et al., 2019). The concept map section can be seen in Fig 1.

3.4. Material Evaluation

In the fourth stage, the results of the analysis from several sources were categorized and then made into a concept map and TLS. The result and On the concept map that has been made, there are stages as shown in Fig 3.

Fig 3 is a concept map of the analysis results. In the concept map, it can be seen the connection of each stage. The first stage discusses water pollution and water treatment. The water pollution section includes the definition of water pollution, its causes, and parameters. There are many ways that can be done to overcome water pollution and

Table 2: Qualitative content analysis.

Content	Analysis Results
Water Pollution	Water pollution is one of the major today's environmental problems. Water pollutants refer to the substances which are capable of making any physical, chemical or biological change in the water body. These have undesirable effect on living organisms. As mentioned earlier, the water used for domestic, agricultural, and industrial purposes is discharged with some undesirable impurities in it [A]. According to WHO estimates, about 80% of water pollution is due to domestic waste. The improper management of water systems may cause serious problems in availability of water. Water resources are most often polluted by industrial effluents. When waste from different industries are discharged without proper treatment into the water [B]. There are three types of water quality parameters: physical, chemical, and biological. Physical parameters of water quality which are turbidity, temperature, color, solids, taste and odor. Chemical parameters of water quality which are pH, CO_2, alkalinity, COD, BOD, and DO. Biological parameters of water quality which are microorganisms, algae, and bacteria [C].
Coagulation Method	Coagulation technology is an economical and simple water treatment technology widely employed at domestic and mass scale, and has been one of the primary purification treatments of water supply [D]. Coagulation is an established water treatment technique that is commonly used for both drinking water production and wastewater treatment. A coagulation process can neutralize the negatively-charged electrostatic field found around naturally occurring suspended particles [E]. Coagulation is the process whereby destabilization of a given suspension or solution is effected. That is, the function of coagulation is to overcome those factors which promote the stability of a given system [F]. Coagulation process has been commonly applied in water treatment systems for a long period due to its capability to remove natural organic matter (NOM) and suspended particles in the raw water [G]. It can be divided into three major groups; inorganic type (conventional), organic polymers, and natural coagulant [H]. This process highlights a water treatment mechanism that stimulates the aggregation of suspended particles to settleable flocs by the destabilization of the charged colloids thus, neutralizing the forces that keep them apart [I]. Many other factors may influence the coagulation process, including initial turbidity of the raw water, type and dosage of coagulant, mixing speed and time, organic content of the treated water, temperature, and coagulation time [J].
Chitosan as natural coagulant for water treatment	In the past few years, a paradigm shift in water and wastewater treatment industries has changed the culture of water operators to adopt and implement sustainable development in the operation. One of the realistic practices is to replace the chemicals used in the treatment processes with "green" chemicals that cause lesser environmental impacts in terms of production, consumption, and secondary waste management [B]. So, in order to resolve problems arising from the use of mineral and synthetic polymers coagulants, natural coagulants are suitable replacements [K]. Chitosan is a natural biopolymer with a modifiable structure and abundant function groups, moreover, it can be processed into various shapes and sizes, making it suitable for various applications [L]. Chitosan have wide applications, and how to improve their flocculation effectiveness is the main focus, because they are cost-effective and environmentally friendly [K]. Chitosan as a coagulant works through two principal systems occurring concurrently during coagulation can be identified, namely, the "bridging model" and the "patch mechanism". The bridging model applies to polymers bearing a similar charge as the colloid. Therefore, bridging is achieved by the adsorption of the polymer to nearby colloids. The patch mechanism, however, results from the reduction of the elec- tronic repulsion between neighbouring colloids by electrostatic association, adsorption, and charge balance of a polymer with inverse charge [M].

this will be discussed in the next stage, that is water treatment. The water treatment

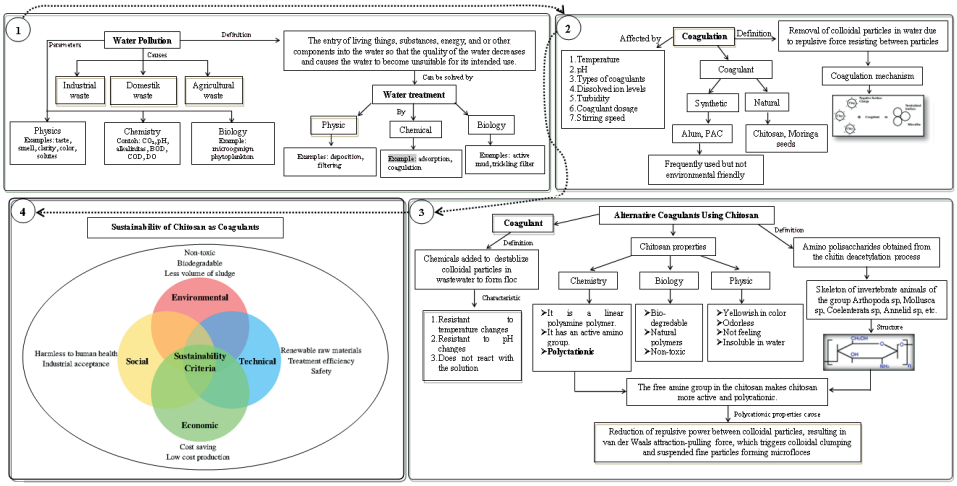

Figure 3: Concept map and TLS of learning of chitosan as natural coagulant for water treatment.

section discusses the physical, chemical, and biological water treatment processes and their methods. From stage 1 to stage 2, it is related to the question “What is the most efficient method for water treatment?”. These questions were answered by stage 2 which discussed coagulation as the most efficient method because coagulation is an economical and simple water treatment technology widely employed at domestic and mass scale, and has been one of the primary purification treatments of water supply. The coagulation section discusses the definition, its factors, mechanism, and types of coagulant. From stage 2 to stage 3, it is related to the question “What solutions can be done to overcome the use of alum and PAC as non environmentally friendly coagulants?” These questions were answered by stage 3 stage 3 discussions about characteristics of coagulant, chitosan as alternative coagulant, chitosan’s properties, chitosan’s structure, action mechanism of chitosan as coagulant.

In the last stage discussed the use of natural coagulants met few of the sustainability criteria. For technical aspects, using natural coagulants is more efficient in terms of treatment, material availability, and safety. For the economic aspect, the production costs are cheaper than using synthetic coagulant. In social aspect, natural coagulant is harmless to human health, industrial acceptance that the using natural coagulants can deliver similar (or better) treatment performance at comparable (or cheaper) cost comparing using chemical coagulants, and Public health improvement that lead to elevation of living conditions. In environmental aspect, using natural coagulants which could reduce the sludge and the toxicity. Overall, these aspects could shed light on the sustainability potential of using natural coagulants in water treatment processes.

4. CONCLUSION

Based on the research that has been done, it can be concluded that content analysis can be carried out through four stages ,they are material collection, descriptive analysis, category selection and material evaluation stage. Based on the research that has been done, it can be concluded that content analysis can be carried out through four stages ,they are material collection, descriptive analysis, category selection and material evaluation stage. This research produces concept maps and TLS. They were obtained from the concept analysis process. The scientist's conceptions obtained are definition, applications, functions, characteristics of coagulation, characteristics of natural coagulant, mechanism reaction of natural coagulant, and the integrated sustainability aspect of natural coagulant. The concept of chitosan as a natural coagulant for water treatment can be integrated in learning through the design of the learning stages. The results of the research can be used as a basis for the development of teaching materials and didactic designs.

5. ACKNOWLEDGMENTS

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