HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

October 2024. 12(5)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 974-986

Ethnochemistry: Analysis the Relevance of Elements Periodic System in the Making of *Kawali* Bugis Bone as a Learning Chemistry Source

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Article History
Received: 28-08-2024
Revised: 03-10-2024
Published: 31-10-2024

Keywords:
ethnochemistry, elements periodic system, *kawali*, learning chemistry source

Abstract
Kawali is one of the war tools of the Bugis Bone community which in its manufacture involves the process of forging, carving, chiseling, and the use of artistic symbols which are used as cultural heritage. Given the importance of knowledge about the benefits of chemistry in life, knowledge about the chemical elements contained in the *kawali* cultural heritage is needed as an effort to foster learning awareness that is integrated with local wisdom values. This research was carried out to reveal the fundamental chemical activities contained in the *kawali* making process starting from the forging and folding process, blade formation, ornament formation and electroplating which can be used as a source of learning chemistry by paying attention to the chemical concept involving chemical elements in the *kawali* making process. This research adopts a qualitative descriptive approach with ethnographic methods, involving observation, interviews, and documentation. The data analysis process is carried out inductively using source triangulation, so that key, primary, and supporting informants are selected for each aspect that is the focus of the study. The results of the research show that the fundamental activities in the process of making *kawali* Bugis Bone include heating and expansion, metal extrusion, metal reduction and electroplating with chemical concepts including metal elements, electron configuration, metal properties, corrosion, redox reactions, and metal alloys, as well as chemical elements involved in the manufacturing process, namely iron, steel containing carbon, manganese, silicon, aluminum, nickel, chromium, cobalt, molybdenum and vanadium.

How to Cite: Yusaerah, N., Imranah, I., Sartika, S., & Fajrah, N. (2024). Ethnochemistry: Analysis the Relevance of Elements Periodic System in the Making of Kawali Bugis Bone as a Learning Chemistry Source. Hydrogen: Jurnal Kependidikan Kimia, 12(5), 974-986. doi:https://doi.org/10.33394/hjkk.v12i5.12811

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INTRODUCTION

The concept of the chemical triangle consisting of macro, micro, and symbolic is the basics of chemistry applied in everyday life. The application of chemical concepts in social systems and cultural products of society shows how broad the impact of chemistry is. Chemical concepts that are relevant to the context of life that contain local wisdom values are known as ethnochemistry. Ethnochemistry is the application of various cultural aspects related to chemistry within communities, illustrating the chemical practices of specific cultural groups. It refers to the study of chemical concepts present in different cultures. Essentially, "ethno" refers to members of a community within a particular cultural context that can be identified through traditions, codes, symbols, myths, and the unique ways they study and draw conclusions (Rahmawati et al., 2017a).

Ethnochemistry based on local wisdom is a part of ethnoscience that serves as a source for chemistry education. Ethnochemistry plays a crucial role in developing local aspects into local wisdom, which becomes a strength of a nation by considering local knowledge, local culture, local skills, and local processes. Through the implementation of learning based on local wisdom, a unique identity and advantages will emerge for graduates. Additionally, this will also become a distinctive feature and strength for educational institutions, ultimately contributing to the excellence of a nation (Asmaningrum et al., 2018).

Ethnochemistry refers to how chemical concepts are applied in people's lives, which is reflected in cultural traditions, cultural symbols, value systems, social systems, and cultural products related to chemical concepts or practices that can be found in various cultures in Indonesia. The use of cultural products in chemistry teaching can provide great benefits in improving the understanding of chemical concepts. This is because the use of cultural products provides deeper meaning to the learning process, so that it can improve the learning achievements of students (Sutrisno et al., 2020; Ismiani et al., 2017; Fadli & Irwanto, 2020). Several studies have shown that integrating cultural elements into chemistry education can enhance students' understanding of abstract concepts that are often difficult to grasp when taught in isolation. For instance, incorporating culturally relevant examples in chemistry instruction not only facilitates student learning but also strengthens their connection to their cultural identity and local knowledge (Hidayatussani et al., 2020).

Although various studies have shown the potential of ethnochemistry in enhancing student understanding and promoting cultural preservation, there are still some weaknesses that need to be addressed. Several previous studies have shown that the integration of cultural elements into chemistry teaching materials or in the learning process is still very rare. The understanding of chemical concepts tends to remain at an abstract level which makes chemistry material still considered as one of the most difficult materials to understand at all levels of education (Rahmawati et al., 2017; Arrozaqu & Setiawan, 2022). Several other ethnochemistry research studies tend to be descriptive and lack in-depth understanding of how cultural integration can systematically influence students' conceptual comprehension. Obstacles in chemistry learning are not only caused by the lack of students' conceptual understanding, but also due to the limitations of chemistry learning materials that can be contextually connected and relevant to students' daily lives. One of them is the limited chemistry learning resources that focus on ethnochemistry.

Chemistry concepts can be integrated with local wisdom by presenting examples that combine chemistry concepts with cultural products. In addition, cultural products can also be used as a 'natural laboratory' to strengthen the understanding of chemistry concepts (Fadli, 2018) (Wahyudiati & Fitriani, 2021). However, the reality shows that the integration of ethnochemistry into learning tools, practical instructions, or the integration of ethnochemistry into the curriculum is still very rare (Wahyudiati, 2021). Moreover, there are shortcomings in the development of chemistry teaching materials that focus on ethnochemistry in Basic Chemistry courses which result in difficulties for students in finding learning materials that can be contextually connected and relevant to everyday life. Ethnochemistry-based learning is very possible to be carried out in Indonesia which is identical to the diversity of tribes and cultures.

Indonesia as a country consisting of many tribes and cultures spread across various islands displays diversity in the characteristics of culture in each region. Although the era continues to develop rapidly through technology and science, it is very important to maintain and preserve the cultural heritage of our ancestors. The diversity of Indonesian culture includes various aspects, such as traditional clothing, traditional weapons, and other elements that illustrate the richness of the culture it has. South Sulawesi is a province in Indonesia that still upholds cultural values and norms that are respected in its community. Among the tribes in South Sulawesi, the Bugis tribe in Bone Regency is famous for the presence of its traditional weapons known as badik or *kawali*. Traditional Bugis Bone weapons, such as *kawali*, are part of a cultural heritage that is still preserved and holds significant artistic and economic value to this day. The process of making *kawali* which involves many chemical elements makes it part of local wisdom that can be applied in learning that adopts ethnochemistry.

Several previous studies have highlighted a gap in integrating traditional weapon-making processes, such as metallurgy, into chemistry education. Most earlier research has primarily focused on the processing of plants, spices, and natural dyes, leaving traditional metallurgy aspects underexplored in the context of chemistry learning. This presents a significant opportunity to investigate how metal production processes within local cultures can provide deeper insights into concepts such as redox reactions, thermochemistry, and material structure.

The development of chemistry teaching materials with an ethnochemical approach can be done through the integration of the periodic system of chemical elements with the local wisdom of Bugis Bone, namely *kawali*. Combining chemistry materials with this local wisdom in the learning process can make it easier for students to understand chemistry theories and concepts because of their relevance to their daily experiences. This allows the unification of old knowledge and experience with new information being learned, increasing student involvement and the results of students' chemistry learning (Arrozaqu & Setiawan, 2022) (Wahyudiati, 2021). Therefore, the integration of ethnochemistry in chemistry learning becomes very important by combining chemical materials with local wisdom of *kawali* Bugis Bone or local wisdom from other regions.

The values reflected in the local wisdom of the Bugis Bone tribe, such as *kawali*, have a relevant connection with the Basic Chemistry teaching material, especially in the topic of the Periodic System of Elements (SPU). This is done through the integration of ethnochemistry into the curriculum, which is adapted to the context of students' lives by using local wisdom as a foundation for understanding concepts and scientific exploration based on nature (Norolayn & Said-Ador, 2017; Sumardi et al., 2020).

Thus, by combining the Periodic System of Elements material with the local wisdom of *kawali* Bugis Bone as a source of chemistry learning and an alternative to natural laboratories, it is expected to not only improve the cognitive aspects of students, but also be able to develop affective and psychomotor dimensions that are very important in the demands of 21st century learning, and become part of the integration of ethnochemistry in the curriculum in universities. In addition, this research not only provides a concrete case study for understanding chemical reactions that are typically studied theoretically, but also demonstrates how chemical principles play a role in producing *kawali* high-quality.

This approach contributes to the gaps in the ethnochemistry literature by highlighting the metallurgical aspects of cultural traditions that have not been extensively researched in the context of chemistry education. In this regard, this study introduces a new approach in using local cultural artifacts as learning media that allows students to understand the relationship between the properties of elements in the periodic table and their practical applications in real life. This research is expected to provide new insights into how the ethnochemistry approach can be more widely applied in chemistry education. Therefore, the urgency of this research is to analyze the relationship between the Periodic System of Elements material and the local wisdom of *kawali* Bugis Bone which can be an effective solution to overcome challenges in chemistry learning by exploring the fundamental chemical activities involved in the process of making *kawali* Bugis Bone.

METHOD

This study employs a qualitative descriptive research design, gathering information on the facts, interpretations, and connections among the phenomena under investigation. The procedure of creating *kawali* is the primary focus of this study. Lappo Ase Village, Awangpone District, Bone Regency, South Sulawesi Province is the focus of the chosen research location.

Data about *kawali* was gathered from a variety of library sources as an initial step in this research process. This research employed source triangulation for its data analysis, identifying important informants, major informants, and supporting informants for each component of the research's focus. The information has to do with the process of preparing *kawali* and the idea of ethnochemistry. In order to select informants who can collaborate effectively, this study employs purposive sampling, taking into account the prerequisites for informant eligibility.

The informants selected in this research were the owner of the *kawali* making business, namely Panre Latuo, the *kawali* craftsman, namely Pak Mendang, and the *kawali* consumer, namely Mr. Mujibur Rahman. This information is related to the activity of making *kawali* and the chemical elements contained in the process of making *kawali*. The data collection technique in this research was conducted through observations made at the *kawali* Bugis Bone production site, focusing on the metallurgy process, tools used, and raw materials. Each step of the production process was recorded, from the selection of raw materials to the final product, in order to identify the relevance of chemical concepts such as redox reactions and physical changes in metals. This involved using an observation guide in the form of a checklist that included observed chemical variables like melting temperature, heating duration, and the types of metals used.

Interviews were conducted with local blacksmiths who possess in-depth knowledge of *kawali* making techniques to gather information related to material selection, heating techniques, and local principles related to the properties of metals. This was guided by a semi-structured interview format that included questions about metallurgy practices and the local terminology used in the production process, as well as documentation (Creswell & Clark, 2017). Inductive data analysis is performed by basing the analysis on the collected data. The phases of defining the research's scope, choosing and identifying informants, interviewing informants, recording, recording data, or documenting and evaluating the data acquired are among the procedures in the research process.

RESULTS AND DISCUSSION

Kawali is one of the war tools of the Bugis Bone community which in its manufacture involves the process of forging, carving, chiseling, and the use of artistic symbols. The materials used to make *kawali* include iron, steel, pamor materials and various other types of materials. *Kawali* is categorized as a work of art handicraft inspired by local non-material culture which has a head, hilt and sheath.

Various tools for people to support the daily life of a region, the names or shapes can vary, but their functions can be the same. This also refers to the mention of badik, keris or *kawali*. *Kawali* refers to a war tool in the form of a sharp weapon like a single-edged dagger and made of iron. The ability to make *kawali* is referred to as a blacksmith or panre bessi. This is because the main material in making *kawali* is iron.

The cultural relevance of *kawali* in the context of chemistry education offers a unique opportunity to engage students by connecting scientific concepts with their heritage and daily lives. Using cultural products like *kawali* not only makes chemistry lessons more relevant but also encourages a deeper understanding of the material being taught. When students learn about the chemical processes involved in the production of *kawali*, such as metallurgy reactions and material properties, they can see the real-world applications of chemistry concepts within their own culture.

This approach aligns with the principles of culturally relevant pedagogy, which emphasizes the importance of integrating students' cultural backgrounds into the learning process to enhance engagement and understanding. Research shows that when students can relate scientific concepts to their cultural experiences and practices, they are more likely to develop a genuine interest in the subject. For example, understanding the roles of elements such as iron, carbon, and nickel in *kawali* production allows students to see the practical implications of chemical reactions, such as oxidation-reduction processes, alloy formation, and the significance of metal properties in everyday items.

Moreover, projects involving the analysis or creation of cultural artifacts like *kawali* can promote experiential learning, making abstract concepts more concrete. This experiential learning can enhance retention and application of knowledge. By participating in activities that connect cultural heritage with scientific inquiry, students not only gain knowledge but also develop a sense of pride in their cultural identity, which strengthens their connection to the material being taught. Overall, integrating *kawali* into chemistry education enhances student engagement, fosters appreciation for culture, and deepens understanding of scientific concepts, paving the way for more meaningful learning experiences. This approach also encourages teachers to create more inclusive curricula that value local knowledge and traditions. The process of making *kawali* Bugis Bone has several stages, some of which involve chemical processes which can be seen in Table 1.

Table 1. Chemical activities in the process of making *kawali* Bugis Bone

Process Stage	**Activity Description**	**Relevant Chemistry Concepts**	**Relation to the Periodic Table**
Selection of Raw Metal Materials	Selection of iron (Fe) as the main material, along with additional elements such as carbon (C), chromium (Cr), nickel (Ni), and manganese (Mn).	Element Properties, Alloy Formation, Mechanical Properties	Elements like Cr, Ni, and Mn belong to the transition metals group, which possess partially filled d-electrons, contributing to strong metallic bonding and corrosion resistance.
Processing Iron Ore	Iron ore is heated to melting point to separate pure iron from iron oxides (Fe_2O_3). This reaction involves reducing iron oxides using carbon as a reducer.	Redox Reactions, Oxidation-Reduction, Thermal Reactions	Reduction of iron oxide: $Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$, where Fe is reduced (the oxide group is removed) and C is oxidized (becoming CO).
Melting and Alloy Formation	Additional elements such as carbon (C) or nickel (Ni) are added to the molten iron to enhance strength and corrosion resistance.	Metal Alloys, Carbide Formation, Mechanical Properties	- Ni enhances thermal stability due to its configuration [Ar] $3d^8\ 4s^2$, reducing expansion. - C forms carbides (Fe_3C), increasing the hardness of the *Kawali*.
Shaping and Forging	The iron is hammered at high temperatures to form the *Kawali* blade. The forging temperature affects the crystal structure of the metal, and rapid cooling	Phase Transformation, Thermodynamics, Activation Energy	Phase transformation of Fe (changing between austenite and martensite) depends on temperature. Elements like Mn lower the transformation temperature and make the

Process Stage	Activity Description	Relevant Chemistry Concepts	Relation to the Periodic Table
	(quenching) alters the mechanical properties.		*Kawali* easier to shape without losing strength.
Rapid Cooling (Quenching)	The *Kawali* is heated to high temperatures and then quickly cooled using water or oil. This process results in a martensitic structure that is harder but more brittle.	Phase Transformation, Thermochemistry, Cooling Rate	The martensitic structure produced from Fe after quenching has higher hardness. Elements such as Cr and C interact with the metal phase to enhance wear resistance.
Tempering (Reheating)	After quenching, the *Kawali* is reheated at a lower temperature to reduce brittleness and enhance toughness.	Phase Transformation, Reaction Kinetics, Activation Energy	Converts the too-brittle martensitic structure into a stronger and tougher form. Elements like Mo and V stabilize the microstructure to improve resistance to mechanical stress.
Formation of Protective Layer	Addition of elements such as chromium (Cr) to form an oxide layer on the surface of the *Kawali*, providing corrosion resistance and improving aesthetics.	Oxide Formation, Redox Reactions, Anti-Corrosion Properties	Formation of Cr_2O_3 oxide layer on the *kawali* surface. The electron configuration of chromium (Cr) ([Ar] $3d^5$ $4s^1$) provides oxide stability, protecting iron from further oxidation.
Finishing and Coating	Gold (Au) or copper (Cu) coating is applied as a final decoration to enhance appearance and provide additional corrosion protection.	Metal Coating, Conductivity, Electrochemical Reactions	Gold (Au) and copper (Cu) play roles in decoration and protection. Gold has high electron affinity ([Xe] $4f^{14}$ $5d^{10}$ $6s^1$), preventing chemical reactions that lead to corrosion.

The results of the *kawali* show that the local wisdom of the community in making *kawali* is still maintained and its existence is believed so that it is worthy of being integrated into chemistry learning as a learning resource.

Figure 1. *Kawali* Bugis Bone

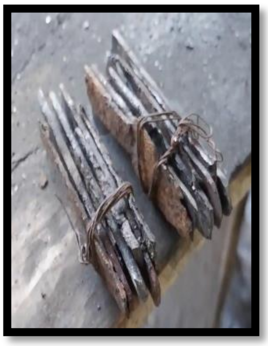
Activities during the making of *kawali* become scientific knowledge that it is useful as a means of introducing students to cultural values and relationship to knowledge. This can open students' insights that the culture found in everyday life is relevant to the science being studied. In this case, ethnochemistry is able to bring together the local wisdom of panre bessi with the concept of chemistry. Therefore, it is able to overcome the separation of local culture from chemistry (Sudarmin et al., 2020). The relevance of the Periodic Table of Elements material contained in the process of making *kawali* Bugis Bone can be seen in Table 2.

Table 2. The relevance of the Periodic Table of Elements in the making *kawali* Bugis Bone

No	Tools and Materials Used		Chemical Concepts
	Tools used		
1	*Pattunungeng*		*Pattunungeng* produces fire from burning charcoal. *Pattunungeng* is used to heat the metal to be forged. (Sodikin et al., 2016); (Yogi, 2016) **Chemistry concept**: Metal properties
2	*Palungeng*		*Palungeng* is a large hammer made of iron and used to forge or shape metal that has been heated. *Palungeng* is the main tool used by iron smiths in making metal equipment. (Yogi, 2016); (Akbar et al., 2017); (Santoso & Alfin, 2021) **Chemistry concepts**: metal elements, electron configuration, metal properties
3	*Lanreseng*		*Lanreseng* is a forging anvil made of iron rods (Yogi, 2016); (Akbar et al., 2017) **Chemical concepts**: metal elements, electron configuration, metal properties

No	Tools and Materials Used	Chemical Concepts
4	*Bak seppu* 	*Bak seppu* is a place where the metal or alloy is heated to a temperature above its critical point followed by rapid cooling. (Arif, 2022); (Prabowo & Sunyoto, 2020) **Chemical concepts**: metal crystal structure, metal properties
5	*Pakkae* 	*Pakkae* is a tool used to stir charcoal during the heating process and is given a wooden handle at the base. (Akbar et al., 2017) **Chemical concepts**: metal elements, electron configuration, metal properties
6	*Paccungkili* 	*Paccungkili* has the form of a small iron stick with a slightly bent end and a wooden handle at the base. This tool has the function of collecting embers that remain in the fire. (Akbar et al., 2017) **Chemistry concepts**: metal elements, electron configuration, metal properties
7	*Pametta* 	*Pametta* is a metal cutting tool in the shape of a wedge and made of iron or steel. (Guspara, 2019); (Yogi, 2016) **Chemistry concepts**: metal elements, metal alloys, electron configuration, metal properties

No	Tools and Materials Used		Chemical Concepts
8	*Kikkiri*		*Kikkiri* has a size of ± 30 cm, made of steel, and has a function to sharpen metal surfaces with hard and large planes. *Kikkiri* with good quality has a rough and not blunt surface. (Sudarwanto & Darmojo, 2018) **Chemistry concept**: metal alloys
9	*Passipi*		*Passipi* is a type of pliers or tongs made of iron and functions to clamp metal materials in the furnace or when forging. (Guspara, 2019); (Yogi, 2016) **Chemistry concepts**: metal elements, electron configuration, metal properties
	Materials used		
10	Iron		Iron is a metal with ductile, soft, malleable and weak properties. Combining metal with other elements aims to improve the quality of the metal. (Arif & Koswara, 2020) **Chemical element**: Iron (Fe)
11	Steel		Steel is a metal alloy with iron as its main element. Steel contains carbon elements that can increase the hardness and strength of steel. In addition, steel with the addition of manganese can increase strength without reducing or slightly reducing strain. The addition of silicon, aluminum and nickel elements to steel can also provide heat, corrosion and wear resistance, and increase strength. The chromium element in steel can make the steel structure smoother and make the steel properties better when hardened. Cobalt, molybdium and vanadium also have a role in steel to reduce sensitivity to heat shock that exceeds the heating limit. (Sulistyo & Prasetyo, 2016) **Chemical elements**: Iron (Fe), Carbon (C), Mangan (Mn), Silicon (Si), Aluminum (Al), Nickel (Ni), Chromium (Cr), Cobalt (Co), Molybdenum (Mo), Vanadium (IN)

No	Tools and Materials Used		Chemical Concepts
12	Pamor		Pamor material is a mixture of materials for making *kawali* in the form of lemme iron. This type of material contains elements of iron, gold, copper, aluminum and nickel which function to provide its own uniqueness and distinctiveness to the *kawali*. (Resmiyanto, 2022); (Irawan et al., 2021); (Harsakya, 2022) **Chemical elements**: Iron (Fe), Gold (Au), Copper (Cu), Aluminum (Al) and Nickel (Ni)

Local wisdom of *kawali* has relevant potential to be integrated with the topic of Periodic System of Elements. Blacksmiths in making *kawali* use equipment as listed in Table 2 with the chemical elements involved, namely iron, steel containing carbon, mangan, silicon, aluminum, nickel, chromium, cobalt, molybdenum and vanadium.

Integration of local wisdom of *kawali* into chemistry teaching materials can provide significant benefits in improving students' learning and utilization of chemical concepts and appreciating the uniqueness of their own culture. Students can see the relevance and direct usefulness of chemical concepts in their own environment and culture (Wahyudiati & Fitriani, 2021) so that they can increase students' motivation, interest and activeness in learning. Thus, the original knowledge of blacksmiths can be used as a source of learning chemistry material on the Periodic System of Elements as a form of cultural preservation effort.

This research has the potential to significantly impact chemistry education in Indonesia, particularly through the application of ethnochemistry. By connecting chemical concepts with local cultural practices, such as the production of *Kawali*, students can gain a better understanding of the real-world applications of chemistry theories, which are often perceived as abstract. This approach can enhance students' interest in chemistry, as they see the relevance of science in their daily lives.

Moreover, the use of ethnochemistry can help preserve local knowledge and raise students' awareness of the cultural richness surrounding them, fostering pride in their cultural heritage. Integrating culture into education not only enhances students' conceptual understanding but also inspires them to be more active in learning and participating in scientific experiments.

Thus, this research can serve as a model for teachers in Indonesia to develop more contextual, relevant, and engaging teaching methods, which in turn can encourage students to delve deeper into chemistry and its applications in everyday life.

CONCLUSION

Based on the research results, it can be concluded that the fundamental chemical activities in the *kawali* making process are heating and expansion, metal extrusion, metal reduction and electroplating with chemical concepts including metal elements, electron configuration, metal properties, corrosion, redox reactions, and metal alloys, as well as chemical elements involved in the manufacturing process, namely iron, steel containing carbon, manganese, silicon, aluminum, nickel, chromium, cobalt, molybdenum and vanadium.

RECOMMENDATIONS

As a suggestion for the future, teachers can integrate the concept of *Kawali* into the chemistry curriculum by designing project-based activities that involve students in the direct production or analysis of *kawali*, such as metallurgical workshops or field trips to *Kawali*-making sites, where students can observe the metallurgical processes, tools, and raw materials used. These activities can be supplemented with an analysis of the chemical reactions involved, such as redox reactions in the reduction of iron ore and alloy formation, as well as the use of relevant elements from the periodic table, such as iron, carbon, nickel, and chromium. Additionally, students could be tasked with creating a chemical safety manual or interdisciplinary projects that connect cultural context with chemistry concepts, enriching students' understanding of the relationship between science and traditional practices in society. This approach not only makes learning more contextual and relevant but also helps students appreciate the local knowledge present in their surroundings.

ACKNOWLEDGEMENTS

Thanks to Rektor IAIN Parepare, the head of LP2M IAIN Parepare, Lecturer colleagues at the Faculty of Tarbiyah especially Tadris IPA IAIN Parepare who has facilitated, provided support in completing this research, given the opportunity to carry out research activities. The *Panre Bessi* in Lappo Ase Village, Awangpone District, Bone Regency, South Sulawesi Province who have facilitated in conducting research. Colleagues and research team who have taken their time to provide inspiration in completing research results.

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