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(Attached Form 6)

学位論文の要旨（論文の内容の要旨）
Summary of the Dissertation (Summary of Dissertation Contents)

論　文　題　目
Dissertation title DEVELOPMENT OF CHEMISTRY TEACHING MATERIALS FOR ENVIRONMENTAL EDUCATION FOR HIGH SCHOOLS IN ZAMBIA

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Introduction

The southern African nation of Zambia is confronted by numerous environmental problems whilst constrained by limited fiscal resources. This study examines the current environmental and educational situation in Zambia and how the Ministry of Education through a revision of its curriculum might inculcate hands-on interactive solutions to local environmental problems and enhance student learning.

The current Zambian educational curriculum has integrated environmental issues across grade levels and subject matter areas, but the subject matter remains abstract with a lack of hands-on activities connecting actual environmental problems to the formal educational material. Just as most Zambian pupils lack the ability to connect the local environment and the theoretical knowledge they learn in schools, the general citizenry demonstrates a lack of concern for the environment as people continue to discard trash and waste indiscriminately without regard for the consequences on human health.

The study examines the current conditions of potable, river, ground and lake waters with research showing areas of impact of different pollutants, especially heavy metals and examines how the Ministry of Education and individual schools could implement a pollutant detection system based on Colorimetry for use in determining water pollution and analysing local solutions as an extension of the high school chemistry curriculum.

The study was divided into five objectives: (1) To investigate the suitableness of curriculum materials for delivering Environmental Education (EE) lessons; (2) To investigate water quality in the Zambian water systems; (3) To develop a pollutant detection method based on Colorimetry; (4) To devise methods of reducing and/or removing pollutants from contaminated water; and (5) To develop a chemistry module for effective teaching/learning of EE in high schools.

Method

The Zambian curriculum was extensively reviewed including the national policy documents; the basic school environmental science syllabus and environmental science textbooks; the high school chemistry syllabus; and corresponding approved chemistry textbooks. Analysis of the textbooks showed what can be improved in the curriculum based on contemporary practices and inadequacies uncovered through the analysis. A subsequent document analysis led to further research in unexplored territories and other areas/regions of the country.

To get an overall picture, 39 parameters and diverse analyses methods were employed for the analysis of water samples obtained from five provinces of Zambia. Analysis provided first-hand information about the nature and extent of water pollution in Zambia. Water is the environmental problem that most affects Zambians and resources remain vulnerable and under constant assault from in-situ latrines, backyard landfills, open dumping,

farming related pollution from fertilizers and pesticides, mining, and industries.

Results and discussion

Analysis of syllabus and textbook

The review of the Zambian curriculum revealed weaknesses: the content is mainly descriptive; pupils are not required to do practical work in EE, nor to engage and connect with the local environment; and facts and concepts are the learning goals. The Zambian Curriculum promotes low order thinking skills such as learning facts and recall. Higher order skills like critical thinking, analysis and problem solving are not emphasised.

Water quality analysis of common ions, DOC and miscellaneous other parameters

Five provinces with different environmental characteristics were evaluated for water pollution with the aim to identify the sources and area(s) most affected. It emerged that the water in Lusaka Province is significantly higher in nitrate (NO_3^-) and sodium (Na) than other provinces covered in the study. Groundwater is most affected by NO_3^- and Na whilst dissolved organic carbon (DOC) was found to be significantly higher in surface water in like amounts in all studied provinces. Results show that pollution is primarily a function of human activities, social amenities and industrial activities in the study areas. The regions with a higher user rate of pit latrines, backyard landfills, and open dumps registered nitrate levels beyond acceptable rates for drinking water.

Heavy metal analysis

Analysis for heavy metals revealed that dissolved manganese (Mn) was the major pollution factor in surface water. Groundwater both near illegal dumpsites and on-site sanitation facilities did not reveal any severe pollution problems beyond drinking water permissible values (PVs). With higher prevalence rates of Mn in the Copperbelt and Lusaka regions, EE activities on pollution can focus on this metal as well as other heavy metals of interest since pollution is dependent on social activities and changes as society evolves.

Seasonal variation of pollution in the Zambezi Watershed

The study reported the seasonal variation of water quality along Lake Kariba, Zambezi River and its tributaries in 2011. Water in the Zambezi River and its tributaries was most polluted in the Late Rain Season (LRS), that is, January to March, with a Water Pollution Index (WPI) of 4.02. The water was least polluted during the Late Dry Season (July to September) with a WPI of 0.44. Water exiting Lake Kariba was generally free of any significant pollution across all seasons. The study proved that pollution changes with season. Therefore, the curriculum should match seasonal trends to make it more relevant. The study of pollutants along the Zambezi river watershed can be scheduled for the LRS since it is the season that is most affected by pollutants.

Development of low cost colorimeters

The colorimeters in this study were designed to use inexpensive electronic components which are readily available. The aim of this study was to present a low-cost design of a colorimeter with regard to the maximum achievable accuracy, precision and versatility in application. After testing the prototype instruments, it was found that Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma (ICP), Digital Water Analyser (DWA) using pack test and the Low-cost Colorimeter (LCC) yielded identical results. It can be said that Mn in a mine effluent water sample and other streams in Lusaka were determined successfully using the LCC and hence can be adopted and applied to measure water related pollution prevalent in a given area.

High school activities on pollution detection and treatment

The study demonstrated how chemistry concepts and their practical applications can be used in EE. The following concepts were utilised in the design of EE lessons: Colorimetry, titrations, precipitation of heavy metal ions using a metal hydroxide, hydrolysis reaction of acid on lignocellulose material, and pyrolysis reaction. The activities under this section were designed to assist pupils find application of the knowledge they learn, a hardly emphasised concept in the Zambian curriculum. These activities not only help in decontaminating water, but also give pupils the chance to engage in hands-on and meaningful activities, and to connect with their environment with activities that are relevant to their lives. This view is supported by Bigge (1964) who reported that activities or materials which are meaningful to students are remembered much better than those which are not.

Conclusion

In making the curriculum flexible and responsive to learners and societal needs, this study bridged the gap of localising some aspects of the high school chemistry curriculum. The localisation of school curriculum, as advocated by the Ministry of Education in Zambia, will allow schools to adapt some aspects of the curriculum to

match the local needs and circumstances, especially, water pollution detection and how it can be treated.

To have a strong basis for adding appropriate content for localising the curriculum, a detailed water analysis was conducted and determined Mn to be the major problem related to heavy metal pollution in Zambia. Mn and Cu were successfully treated from contaminated water. Nitrate was another prevalent problem in areas with in-situ sanitation and illegal landfills. Therefore, this study recommends that pupils are made aware of the sources of nitrates and possible detection methods (through classroom activities). Thereafter embark on lifestyle changes and proper land-use management practices such as refraining from indiscriminate dumping of garbage, avoiding the use of unprotected pit latrines, and careful assessment of the possible sources of contamination relative to the wells/boreholes and other sources of water in their community. Using the LCC, pupils can determine the contaminated sources of water and recommend the suitability of such for school or public service. This study found surface water to be relatively free of NO_3^- contamination. Therefore, it is recommended, where possible, to blend high-nitrate groundwater with surface water that has lower nitrate concentrations, and in the process applying the chemistry concept of dilution. The analysis of the water from Lake Kariba, Zambezi River and its tributaries revealed that water was most polluted during the late rain season (January to March); the major pollutants were different from season to season, and so it would be appropriate to design the curriculum to take into account the changing nature and intensity of the pollutants across the seasons. The curriculum development process in Zambia covers a global view of the new trends, strategies and practices (for example, lead poisoning in the global context, greenhouse effect, ozone layer depletion, acid rains and its effects). Nonetheless, this study recommends to curriculum developers to embrace and accord higher priority to activities that have a direct bearing on the pupils' lives, and ideas which could fit in the local and national situations.