

**PHYSICO-CHEMICAL ANALYSIS OF WATER SUPPLY
FROM MAJOR DEEP WELLS IN CENTRAL
LUZON STATE UNIVERSITY**

JOHN MARC C. GANZON

An Undergraduate Thesis Submitted to the Faculty of the Department of Environmental
Science, College of Arts and Sciences, Central Luzon State University,
Science City of Muñoz, Nueva Ecija, Philippines
In Partial Fulfillment of the Requirements
for the Degree of

**BACHELOR OF SCIENCE IN ENVIRONMENTAL SCIENCE
(Environmental Chemistry)**

JUNE 2019

ACCEPTANCE SHEET

This undergraduate thesis entitled "PHYSICO-CHEMICAL ANALYSIS OF WATER SUPPLY FROM MAJOR DEEP WELLS IN CENTRAL LUZON STATE UNIVERSITY," prepared and submitted by JOHN MARC C. GANZON in partial fulfillment of the requirements for the degree of BACHELOR OF SCIENCE IN ENVIRONMENTAL SCIENCE (ENVIRONMENTAL CHEMISTRY), is hereby accepted:


LUZVIMINDA S. QUITOS, Ph.D.
Adviser

5-30-2019
Date Signed


REDEL L. GUTIERREZ, Ph.D.
Critic

5/30/2019
Date Signed


LUZVIMINDA S. QUITOS, Ph.D.
Department Research Coordinator

5-30-2019
Date Signed


Accepted as partial fulfillment of the requirements for the degree of BACHELOR OF SCIENCE IN ENVIRONMENTAL SCIENCE (ENVIRONMENTAL CHEMISTRY):


CESAR V. ORTINERO, Ph.D.
Chair, Department of Environmental Science

5-31-2019
Date Signed


RICH MILTON R. DULAY, M.Sc.
College Research Coordinator

5/31/19
Date Signed


EVARISTO A. ABELLA, Ph.D.
Dean, College of Arts and Sciences

5/31/19
Date Signed

BIOGRAPHICAL SKETCH

The author's name is John Marc C. Ganzon and he was born in Llanera, Nueva Ecija. His parents, Thelma and Zaldy Ganzon, raised him. He finished his elementary education at Inanama Elementary School where he graduated with flying colors as Class Valedictorian, his high school at Charles Angel Montessori School where he graduated having 1st honorable mentioned, and attended college education at Central Luzon State University, taking the degree of Bachelor of Science in Environmental Science having Environmental Chemistry as his field of specialization.

During his college years, he was a dedicated student-athlete where he won Silver and Gold Medals on both beach volley and indoor volleyball men category at State, Colleges, and Universities Athletic Association (SCUAA-III).

Chemistry was his first course to serve as his first stepping-stone before entering the Philippine Drug Enforcement Agency (PDEA). He then later realized that environmental science fits him better where he would have more chance to express his ideas and thoughts with the help of scientific literature, principles, and theories. Environmental Science Major in Chemistry perhaps is much similar to Chemistry. For him, it is a very inspiring and highly relevant course because it could provide concrete and rational solutions to different problems and issues concerning the three important sectors; environment, society and economy. With the help of his effective professor and mentor at Central Luzon State University, they enlightened his perception on how and what an environmental scientist should do and must do.

ACKNOWLEDGMENT

Firstly, I would like to express my sincere gratitude to my adviser Dr. Luzviminda S. Quitos, for the continuous support to my study, for her patience, motivation, and immense knowledge. Her guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better adviser and mentor for my BS study.

Besides my adviser, I would also like to thank Dr. Redel L. Gutierrez, my critic, for his insightful comments and encouragement, but also for the hard question, which incited me to widen my research from various perspectives.

To Sir Ron Del Pilar and Mam Onneth Tejada, whose statistical expertise was invaluable during the analysis and interpretation of the data that has been collected, I am indebted to the both of you. Thank you for providing statistical analysis to my thesis.

Nobody has been more important to me in the pursuit of this study than the members of my family. I would like to thank my parents, whose love and guidance are with me in whatever I pursue. They are my ultimate role models.

I greatly appreciate the help I received from various people such as, Professor Belle Villaver, Mr. John Carlo Lising Tecson, Attorney Rodolfo T. Tobias, Mam Magdalena Galang, Mam Anna Cielo G. Barza, Mam Benilda Lorenzo, Mam Sharon Lazaro, Mam Danila Paragas and Kuya Christian Dela Cruz who provide assistance, inspired and motivated me to finish my thesis.

My thanks also go out to the support I received from my longtime friends to whom I consider as my brothers during my stay in CLSU. To Engr. John Kim Dela Cuadra, Engr. Anthony Espe, Teacher Rhyden Ramirez and to my Kosas in the Athletes

Dorm, Limwel Orzame, Kenneth De Ocampo, Leonard Martin and Frederick Dela Cruz, thank you guys for believing in me.

Lastly all praises, honor and glory to God for helping me to persevere in hardships, sleeplessness, distress and His richest grace and mercy for the accomplishment of this thesis.

TABLE OF CONTENTS

	PAGE
LIST OF FIGURES	ix
LIST OF APPENDICES	x
LIST OF APPENDIX TABLES	xi
LIST OF APPENDIX FIGURES	xiii
ABSTRACT	xiv
INTRODUCTION	1
Background of the Study	1
Objectives of the Study	3
Significance of the Study	4
Scope and Limitations of the Study	5
Time and Place of the Study	6
REVIEW OF RELATED LITERATURE	7
Water Quality	7
Background Information about the Site	8
Deep Well 1	8
Deep Well 2	9
Deep Well 3	9
Deep Well 4	10
Deep Well 5	10
Deep Well 6	11
Parameters	11
Physico-Chemical Characteristic	11
pH	11
Temperature	12
Total Dissolved Solid	12
Sulfate	13
Nitrate	13
Total Suspended Solid	15
Total Hardness	15

Toxic Inorganic Substances	16
Dissolved Oxygen	17
Sampling and Analysis	17
Water Pollutants and their Sources	18
Non-point & Point Sources	19
Related Studies	19
CLSU Water Distribution Map	22
METHODOLOGY	23
Sampling Sites	23
Collection of Samples	23
Sampling for Physico-Chemical Analysis	24
Physico-Chemical Analysis	25
<i>In-situ</i> Analysis	25
Total Suspended Solid	25
Total Hardness	27
Sulfate	28
Nitrate	29
Heavy Metals	30
RESULTS AND DISCUSSION	31
Analysis of Parameters	31
<i>In situ</i> Analysis	31
pH	31
pH differences among station	31
pH differences among location	32
Total Dissolved Solids	33
Total Dissolved Solids (TDS) differences among station	33
Total Dissolved Solids (TDS) differences among location	34
Temperature	35
Temperature differences among station	36

Temperature differences among location	36
Dissolved Oxygen	38
Dissolved Oxygen (DO) differences among station	38
Dissolved Oxygen (DO) differences among location	38
Physico-Chemical Analysis	40
Total Hardness	40
Sulfates	42
Lead	43
Cadmium	46
Total Suspended Solids	47
Nitrates	48
SUMMARY, CONCLUSION AND RECOMMENDATIONS	51
LITERATURE CITED	55
APPENDICES	61

LIST OF FIGURES

FIGURE		PAGE
1	Central Luzon State University Water Distribution Map	22
2	Average pH of collected water samples from six different deep wells in CLSU	32
3	Average TDS concentration of collected water samples from six different deep wells in CLSU	34
4	Average temperature of collected water samples from six different deep wells in CLSU	37
5	Average DO (mg/L) of collected water samples from six different deep wells in CLSU	39
6	Average hardness (mg/L) of collected water samples from six different deep wells in CLSU	41
7	Average sulfates concentrations of collected water samples from six different deep wells in CLSU	42
8	Average lead concentrations of collected water samples from six different deep wells in CLSU	44
9	Average cadmium concentrations of collected water samples from six different deep wells in CLSU	46
10	Average TSS concentrations of collected water samples from six different deep wells in CLSU	48
11	Average nitrate concentrations of collected water samples from six different deep wells in CLSU	49

LIST OF APPENDICES

APPENDIX		PAGE
I	Raw data and ANOVA tables	62
II	Comparison of the parameters by location	83
III	Comparison of the parameters by station	85
IV	Standard calibration curves	87

LIST OF APPENDIX TABLE

APPENDIX TABLE	PAGE	
1	pH values of water samples at six different deep wells in CLSU	62
2	One way analysis of variance by location (Near)	63
3	TDS of water samples at six different deep wells in CLSU (mg/L)	64
4	One way analysis of variance by location (Middle)	65
5	Temperature of water samples at six different deep wells in CLSU	66
6	One way analysis of variance by location (Far)	67
7	Dissolved Oxygen values at six different deep wells in CLSU	68
8	One way analysis of variance by station (Deep Well 1)	69
9	Total hardness values collected at six different deep wells in CLSU	69
10	One way analysis of variance by station (Deep Well 2)	70
11	Sulfates values collected at six different deep wells in CLSU	70
12	One way analysis of variance by station (Deep Well 3)	70
13	Total Suspended Solids collected at six different deep wells in CLSU	71
14	One way analysis of variance by station (Deep Well 4)	72
15	Lead values collected at six different deep wells in CLSU	73
16	One way analysis of variance by station (Deep Well 5)	74
17	Cadmium values collected at six different deep wells in CLSU	75
18	One way analysis of variance by station	76
19	Nitrates values collected at six different deep wells in CLSU	76

LIST OF APPENDIX TABLE

APPENDIX TABLE		PAGE
1	pH values of water samples at six different deep wells in CLSU	62
2	One way analysis of variance by location (Near)	63
3	TDS of water samples at six different deep wells in CLSU (mg/L)	64
4	One way analysis of variance by location (Middle)	65
5	Temperature of water samples at six different deep wells in CLSU	66
6	One way analysis of variance by location (Far)	67
7	Dissolved Oxygen values at six different deep wells in CLSU	68
8	One way analysis of variance by station (Deep Well 1)	69
9	Total hardness values collected at six different deep wells in CLSU	69
10	One way analysis of variance by station (Deep Well 2)	70
11	Sulfates values collected at six different deep wells in CLSU	70
12	One way analysis of variance by station (Deep Well 3)	70
13	Total Suspended Solids collected at six different deep wells in CLSU	71
14	One way analysis of variance by station (Deep Well 4)	72
15	Lead values collected at six different deep wells in CLSU	73
16	One way analysis of variance by station (Deep Well 5)	74
17	Cadmium values collected at six different deep wells in CLSU	75
18	One way analysis of variance by station	76
19	Nitrates values collected at six different deep wells in CLSU	76

20	Comparison of Means among NO ₃ Station	77
21	Analysis of Variance for NO ₃	77
22	Analysis of Variance for Total Suspended Solids	77
23	Comparison of Means among Total Suspended Solids	78
24	Analysis of Variance for Total Hardness	78
25	Comparison of Means among Total Hardness	78
26	Sulfates values collected at six different deep wells in CLSU	79
27	Analysis of Variance for Heavy Metals (Lead)	79
28	Comparison of Means among Lead	80
29	Analysis of Variance for Heavy Metals (Cadmium)	81
30	Comparison of Means among Heavy Metals (Cadmium)	82
31	Total Suspended Solids of six deep wells in CLSU	82
32	Comparison of ANOVA by location (Near)	83
33	Comparison of parameters by location (Middle)	83
34	Comparison of parameters by location (Far)	84
35	Comparison of parameters by Station (Deep Well 1)	85
36	Comparison of parameters by Station (Deep Well 2)	85
37	Comparison of parameters by Station (Deep Well 3)	85
38	Comparison of parameters by Station (Deep Well 4)	86
39	Comparison of parameters by Station (Deep Well 5)	86
40	Comparison of parameters by Station (Deep Well 6)	86

LIST OF APPENDIX FIGURES

APPENDIX FIGURE		PAGE
1	Calibration curve of nitrates	87
2	Calibration curve of lead	87
3	Calibration curve of cadmium	88

oxygen content of water samples was found to be significantly different with respect to station at Deep Well 2 and among locations on Deep Well 5 at nearest and on Deep Well 2 & 3 at middle. The result of total hardness analysis shows that the water samples with respect to stations are all significantly different. In terms of location, all were not significantly different. Sulfates on the other hand are only present at Deep Well 2, lead concentrations were significantly different at Deep Well 1, 2 & 6, and cadmium content of the water samples was significantly different in Deep Well 2 & 3.

Keywords: physico-chemical analysis; groundwater; water quality

LITERATURE CITED

- Ademe, A., & Alemayehu, M. (2014). Source and determinants of water pollution in Ethiopia: distributed lag modeling approach. *Intellectual Properties Rights: Open Access*, 2(2), 1-6. Retrieved from <https://doi.org/10.4172/2375-4516.1000110>
- Alrumman, S. A., & El-kott, A. F. (2016). Water pollution: source & treatment. *American Journal of Environmental Engineering*, 6(3), 88-98. Retrieved from <https://doi.org/10.5923/j.ajee.20160603.02>
- American Water Works Association, Inc. (2011). *Water quality and treatment* (3rd ed.). USA: McGraw-Hill Book Company.
- Assi, M. A., Hezmee, N. M., Haron, A. W., Sabri, M., Yusof, M., & Rajion, M. A. (2016). The detrimental effects of lead on human and animal health. *Veterinary World*, 9(6), 660-671. Retrieved from <https://doi.org/10.14202/vetworld.2016.660-671>
- Ayele, D. (2015). *Environmental Chemistry* (3rd ed.). Africa: Creative Commons.
- Bashir, M. T. (2012). Health effects from exposure to sulphates and chlorides in drinking water. *Pakistan Journal of Medical and Health Sciences*, 6(3), 648-652. Retrieved from <https://doi.org/10.1155/2017/7908183>
- Bharadwaj, N. D., Uchharia, D. K., & Jain, R. (2016). Physical-chemical analysis of drinking water of government hospitals of Gwalior City. *International Research Journal of Engineering and Technology*, 3(3), 1578-1582.
- Boyd, C. E., Tucker, C. S., & Viriyatum, R. (2011). Interpretation of pH, acidity, and alkalinity in aquaculture and fisheries. *North American Journal of Aquaculture*, 73(4), 403-408. Retrieved from <https://doi.org/10.1080/15222055.2011.620861>
- Burke, F., Hamza, S., Huda, S., Azam, M., & Khan, I. (2016). Impact of cadmium polluted groundwater on human health: Winder, Balochistan. *SAGE Journal*, 6(1), 1-8. Retrieved from <https://doi.org/10.1177/2158244016634409>
- Burow, K. R., Nolan, B. T., Rupert, M. G., & Dubrovsky, N. M. (2010). Nitrate in groundwater of the United States, 1991–2003. *Environmental Science and Technology*, 44(13), 4988–4997. Retrieved from <https://doi.org/10.1021/es100546y>
- Butler, D., & Davies, J. W. (2011). *Urban Drainage* (3rd ed.). NY: Spon press.
- Davis, M. L. (2011). *Water and wastewater engineering* (1st ed.). NY: McGraw-Hill Education

- Davis, M. L., & Cornwell, D. A. (2008). *Environmental Engineering* (4th ed.). NY: McGraw-Hill.
- Drechsel, P., Scott, C. A., Raschid-Sally, L., Redwood, M., & Bahri, A. (2010). *Wastewater Irrigation and Health* (2nd ed.). London: Earthscan.
- Estefan, G., Sommer, R., & Ryan, J. (2013). *Methods of soil, plant and water analysis* (3rd ed.). Beirut, Lebanon: ICARDA (International center for agricultural research in the dry areas).
- Eteng, M., Berena, G., Anacletus, F., & Basse, S. (2015). Effect of exposure to lead and cadmium in drinking water sources from Nigeria's Niger delta region on Fecundity in albino wister rats. *Journal of Biotechnology and Biochemistry*, 1(6), 37-39.
- Halder, J., & Islam, M. (2015). Water pollution and its impact on the human health. *Journal Of Environment And Human*, 2(1), 36-46. Retrieved from <https://doi.org/10.15764/EH.2015.01005>
- Hayes, C., & Skubala, N. (2009). Is there still a problem with lead in drinking water in the European Union?. *Journal of Water and Health*, 7(4), 569-580. Retrieved from <https://doi.org/10.2166/wh.2009.110>
- Hu, H., & Huang, G. (2014). Monitoring of non-point source pollutions from an agriculture watershed in South China. *Water*, 6(1), 3828-3840. Retrieved from <https://doi.org/10.3390/w6123828>
- Hudak, P. (2010). Sulfate and chloride concentrations in Texas aquifers. *Environment International*, 26(2), 55-61. Retrieved from [https://doi.org/10.1016/s0160-4120\(00\)00078-7](https://doi.org/10.1016/s0160-4120(00)00078-7)
- Islam, M. R., Sarkar, M. I., Afrin, T., Rahman, S., Talukder, R., Howlader, B., & Khaleque, M. (2016). A study on total dissolved solids and hardness level of drinking mineral water in Bangladesh. *American Journal of Applied Chemistry*, 4(5), 164-169. Retrieved from <https://doi.org/10.11648/j.ajac.20160405.11>
- Jan, A., Azam, M., Ali, K., Choi, A., Siddiqui, A., & Rizwanul, H. (2015). Heavy metals and human health: mechanistic insight into toxicity and counter defense system of antioxidants. *Journal of Environment and Human*, 16(5), 29592-29630. Retrieved from <https://doi.org/10.3390/ijms161226183>

- Jagessar, R. C., & Sooknundun, L. (2011). Determination of nitrate anion in waste water from nine selected areas of coastal Guyana via a spectrophotometric method. *International Journal of Research and Reviews in Applied Sciences*, 7(2), 203-212. Retrieved from https://doi.org/10.1007/978-3-642-370069_7
- Keast, G., & Johnston, R. (2008). *UNICEF handbook on water quality*. NY: United Nations Children's Fund.
- Khademikia, S., Rafiee, Z., Amin, M., Poursafa, P., Mansourian, M., & Modaberi, A. (2013). Association of nitrate, nitrite, and total organic carbon in drinking water and gastrointestinal disease. *Journal of Environmental and Public Health*, 1(1), 1-4. Retrieved from <https://doi.org/10.1155/2013/603468>
- Kipngetch, T. E., Hillary, M., & Swamy, T. A. (2013). Determination of levels of phosphates and sulphates in domestic water from three selected springs in Nandi County, Kenya. *International Journal of Pharmacy and Life Sciences*, 4(7), 2828-2833.
- Kumar, M., & Puri, A. (2012). A review of permissible limits of drinking water. *Indian Journal of Occupational and Environmental Medicine*, 16(1), 40-44. Retrieved from <https://doi.org/10.4103/0019-5278.99696>
- Krause, S., Tecklenburg, C., Munz, M., & Naden, E. (2013). Streambed nitrogen cycling beyond the hyporheic zone: Flow controls on horizontal patterns and depth distribution of nitrate and dissolved oxygen in the upwelling groundwater of a lowland river. *Journal of Geophysical Research: Biogeosciences*, 118(1), 54-67. Retrieved from <https://doi.org/10.1029/2012JG002122>
- Li, X., Masuda, H., Kusakabe, M., Yanagisawa, F., & Zeng, H.-a. (2008). Degradation of groundwater quality due to anthropogenic sulfur and nitrogen contamination in the Sichuan Basin, China. *Geochemical Journal*, 40(1), 309-332. Retrieved from <https://doi.org/10.2343/geochemj.40.309>
- Malakootian, M., Mansoorian, H., & Moosazadeh, M. (2010). Performance evaluation of electrocoagulation process using iron-rod electrodes for removing hardness from drinking water. *The International Journal on the Science and Technology of Desalting and Water Purification*, 255(3), 67-71. Retrieved from <https://doi.org/10.1016/j.desal.2010.01.015>
- Martinez, F. F. (2003). *Chemical and Bacteriological Analysis of Water Supply from Selected Areas in San Jose City and Science City of Muñoz, Nueva Ecija* (Unpublished undergraduate thesis). Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines.

- Ngang, B., & Agbazue, V. (2016). A seasonal assessment of groundwater pollution due to biochemical oxygen demand, chemical oxygen demand and elevated temperatures in Enugu Northern Senatorial District, South East Nigeria. *Journal of Applied Chemistry*, 1(7), 66-73. Retrieved from <https://doi.org/10.9790/5736-0907016673>
- Ogston, A. G. (2008). The definition and meaning of pH. *Physiological Reviews*, 27(2), 228-239. Retrieved from <https://doi.org/10.1152/physrev.1947.27.2.228>
- Ojo, O. I., Otieno, F. O., & Ochieng, G. M. (2012). Groundwater: characteristics, qualities, pollutions and treatments: an overview. *International Journal of Water Resources and Environmental Engineering*, 4(6), 162-170. Retrieved from <https://doi.org/10.5897/IJWREE12.038>
- Okparaocha, F. J., Oyeleke, P. O., & Abiodun, O. A. (2016). Determination of heavy metals in public tap water in Ibadan Metropolis, Southwestern Nigeria. *American Chemical Science Journal*, 15(4), 1-9.
- Olajaire, A., & Imeokparia, F. (2011). Water quality assessment of Osun river: studies on inorganic nutrients. *Environmental Monitoring Assessment*, 69, 17-28. Retrieved from <https://doi.org/10.1023/A:1010796410829>
- Oyem, H., & Ezeweali, D. (2014). Temperature, pH, electrical conductivity, total dissolved solids and chemical oxygen demand of groundwater in Boji-BojiAgbor/Owa area and immediate suburbs. *Academic Journals*, 8(8), 444-450. Retrieved from <https://doi.org/10.3923/rjes.2014.444.450>
- Parker, R. (2012). *Aquaculture Science* (3rd Edition). US: Cengage Learning.
- Patil, P., Sawant, D., & Deshmukh, R. (2012). Physico-chemical parameters for testing of water - a review. *International Journal Of Environmental Sciences*, 3(3), 1194-2107. Retrieved from <https://doi.org/10.6088/ijes.2012030133028>
- Patni, N. K., Masse, L., & Jui, P. Y. (2008). Groundwater Quality under conventional and no tillage: I. nitrate, electrical conductivity, and pH. *Journal of Environment Quality*, 27(4), 869. Retrieved from <https://doi.org/10.2134/jeq1998.004724250027000>
- Ramakrishnaiah, C. R., Sadashivaiah, C., & Ranganna, G. (2009). Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka state, India. *E-Journal of Chemistry*, 6(2), 523-530. Retrieved from <https://doi.org/10.1155/2009/757424>

- Ramya, P., Babu, A., Reddy, E., & Rao, L. (2015). A study on the estimation of hardness in groundwater samples by EDTA titrimetric method. *International Journal of Recent Scientific Research*, 6(6), 4505-4507.
- Rose, S., & Long, A. (2012). Monitoring dissolved oxygen in ground water: some basic consideration. *Groundwater Monitoring and Remediation*, 3(8), 1745-6592. Retrieved from <https://doi.org/10.1111/j.1745-6592.1988.tb00981.x>
- Sahoo, P. K., Powel, M. A., & Kangjoo, K. (2016). Managing groundwater nitrate contamination from livestock farms: Implication for nitrate management guidelines. *Environmental Science and Pollution Research*, 2(3), 178-187. Retrieved from <https://doi.org/10.1007/s40726-016-0033-5>
- Satyanarayana, P., Raju, A. N., Harikrishna, K., & Viswanath, K. (2013). Urban groundwater quality assessment: a case study of greater Visakhapatnam municipal corporation area (Gvmc), Andhra Pradesh, India. *International Journal of Engineering Science Invention*, 2(5), 20-31. Retrieved from <https://doi.org/10.1007/s10661-011-2333-y>
- Sengupta, P. (2013). Potential health impacts of hard water. *International Journal of Preventive Medicine*, 4(8), 866-875.
- Shyamala, R., Shanthi, M., & Lalitha, P. (2008). Physicochemical analysis of borewell water samples of Telungupalayam area in Coimbatore district, Tamilnadu, India. *Journal of Chemistry*, 5(4), 924-929. Retrieved from <https://doi.org/10.1155/2008/152383>
- Singh, S., Raju, J., & Ramakrishna, C. (2015). Evaluation of groundwater quality and its suitability for domestic and irrigation use in parts of the Chandauli-Varanasi region, Uttar Pradesh, India. *Journal of Water Resource and Protection*, 7(1), 572-587. Retrieved from <https://doi.org/10.4236/jwarp.2015.77046>
- Sumnu, G. (2011). A review on microwave baking of foods. *International Journal of Food Science and Technology*, 36(2), 117-127. Retrieved from <https://doi.org/10.1046/j.1365-2621.2001.00479.x>
- Torda, M. O. (1991). *Groundwater Analysis in Rizal and Llanera, Nueva Ecija* (Unpublished undergraduate thesis). Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines.

- Triantafyllidou, S., & Edwards, M. (2012). Lead (Pb) in tap water and in blood: implications for lead exposure in the body. *Critical Reviews in Environmental Science and Technology*, 42(13), 1297-1352. Retrieved from <https://doi.org/10.1080/10643389.2011.556556>
- Triantafyllidou, S., Lambrinidou, Y., & Edwards, M. (2009). Lead exposure through drinking water: lessons to be learned from recent U.S. experience. *Global NEST Journal*, 11(3), 341-348.
- Winograd, I., & Robertson, F. (2013). Deep oxygenated ground water: anomaly or common occurrence? *Science Mag*, 216(4551), 1227-1230. Retrieved from <https://doi.org/10.1126/science.216.4551.1227>
- World Health Organization. (2017). *Guidelines for drinking-water quality* (4th ed.). Geneva: World Health Organization.
- Yousefi, Z., Tahmtan, R. M., & Kazem, F. (2015). Temporal and spatial variation of hardness and total dissolved solids concentration in drinking water resources of Ilam City using Geographic Information System. *Environmental Health Engineering and Management Journal*, 2(4), 203-209.