Energy Drinks R&D Project report 2019-20

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1 author:

Farah Tasneem
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Project Completion Report of R&D Project for the Fiscal Year of 2019-2020 Supported by the Ministry of Science and Technology

Name of the Program/Project

Assessment of Physico-Chemical Parameters of Energy Drinks Commercially Available in Bangladesh and Its Human Health Risk Evaluation.

Name of the Project Director: Farah Tasneem Ahmed

Group: Engineering

Name of the University/Organization: Bangladesh Atomic Energy Commission

Chapter One

Introduction

Introduction

Energy drinks are non-alcoholic beverages claimed to give extra burst of energy for daily obligation and promote wakefulness, maintain alertness, and provide cognitive and mood enhancement. They are carbonated beverages that contain significant quantities of sugar and caffeine as well as blends of exotic herbal extracts, B vitamins and amino acids meant to give consumers short term boost in energy and increase mental alertness (Alford *et al.*, 2001). Energy drinks generally contain methylxanthines (including caffeine), B vitamins, carbonated water, guarana, yerba mate, acai, and taurine, plus various forms of ginseng, maltodextrine, inositol, carnitine, creatine, glucuronolactone, and ginkgo biloba etc. (Adepoju and Ojo, 2014).

In the UK, "Lucozade Energy" was originally introduced in 1929 as a hospital drink for "aiding the recovery". But in 1987 when Red Bull was introduced in Austria, it became more popular in the 1990s following its introduction to the United States. Since then the sale of this drink has increased exponentially. In 2006, the energy drink market grew by 80% (Foran *et al*., 2011). This is because manufactures claimed that the drinks can boost energy levels as well as physical endurance, improve concentration and reaction speed (Van den Eynde *et al.*, 2008). Recently a number of different energy drinks have been introduced in the Bangladesh market to provide an energy boost or as dietary supplements. These drinks are marketed specifically to youth and young adults.

According to the medical science, caffeine enters the bloodstream within 10 minutes of consuming an energy drink, triggering a rise in heart rate and blood pressure. Over the next 15-45 minutes, caffeine levels in the bloodstream peak. As a result, an individual will feel more alert and experience improved concentration. All of the caffeine is absorbed within 30-50 minutes of consuming an energy drink and the liver responds to this by soaking up more sugar into the bloodstream. Within an hour, the effects of the caffeine will begin to subside and a sugar crash may occur. Energy levels will begin to feel low and tiredness will set in. It will take around 5-6 hours for the body to achieve a 50% reduction in the amount of caffeine in the bloodstream - known as the "half-life" - It takes an average of 12 hours for the body to completely remove the caffeine from the bloodstream, though this does depend on individual factors. The withdrawal effect of caffeine include headache, irritability, constipation etc.

Although many energy drinks are promoted as being nut foods, boosting health, energy, or otherwise having sought after benefits, there is some concern among health professionals that these beverages, and the drinking behaviors of the targeted consumers, may in fact have adverse health consequences (Millam *et al.*, 2017). The most commonly reported adverse effects include insomnia, nervousness, headache, and tachycardia (Clauson and McQueen, 2008). The other potential risks associated with energy drink consumption include:

- Caffeine overdose (which can lead to a number of symptoms, including palpitations, high blood pressure, nausea and vomiting, convulsions and, in some cases, even death)
- Type 2 diabetes – as high consumption of caffeine reduces insulin sensitivity
- Late miscarriages, low birth weight and stillbirths in pregnant women
- Neurological and cardiovascular system effects in children and adolescent
- Attention – seeking behavior
- Use and dependence on other harmful substances
- Poor dental health, obesity

In many types of energy drinks, major and trace element concentrations have been assessed. Most often, essential trace elements, such as Cu, Fe, Mn and Zn (Paredes *et al.*, 2006) and toxic metals like Pb and Cd were quantified. (Mohammed *et al.*, 2012). Infrequently studies of essential macro elements, such as Ca, K, Mg, Na etc. have been conducted (Majeda *et al*., 2013). Only a few researchers in Bangladesh were worked on this energy drinks and almost all of them had gave preferences on the physical parameters like pH, electrical conductivity (EC), total dissolved solid (TDS), turbidity etc. along with the caffeine, reducing sugar and alcohol contents in it (Hossain *et al.*, 2016 and Hossain and Jahan *et al.*, 2015).

Objective(s)

The studies on energy drinks are very fresh in Bangladesh. So, the primary objective of this research is to measure the physical parameters like pH, EC, TDS, Turbidity etc. and to identify the heavy metal contents present in energy drinks. The concentration of different heavy metals will be compared by the drinking water standards of WHO, USEPA and Bangladesh National Standards. Also, from this study we can assess the health risks of heavy metals associated with the consumption of energy drinks in Bangladesh.

Socio-Economic Importance:

The popularity of energy drinks and the escalation in their consumption among adolescents and young adults have brought worries regarding general health and well-being of these consumers. Adolescents and young adults are often uninformed about the content of energy drink (Rath, 2012). Although many energy drinks are promoted as being nutraceutical foods, boosting health, energy or otherwise having sought-after benefits, there is some concern among health professionals that these beverages and the drinking behaviors of the targeted consumers may in fact have adverse health consequences. The most commonly reported adverse effects include insomnia, nervousness, headache, and tachycardia (Gimba, *et al*., 2014).

From the ingredients of energy drinks we found the presence of sodium (Na), potassium (K), magnesium (Mg) in it which is essential for our dietary. Calcium (Ca) is very useful for bone development and teeth. Copper (Cu) is helpful as the production of red blood cells and it activates our immune system. Iron (Fe) is a major constituent of hemoglobin and myoglobin which are required for oxygen transport in the body. Anemia caused by the deficiency of iron. Manganese (Mn) is a major component of the mitochondrial antioxidant enzyme. Zinc (Zn) is handy in reproductive functions, nickel (Ni) in functional for weak bone construction, cobalt (Co) is a part of Vitamin B_{12} and chromium (Cr) is a factor in the regulation of sugar levels. All these heavy metals show their constructive effects only when they are found in the body in the tolerable edge. But excess of any element can cause detrimental consequences and can affect our nervous system (Mn), pulmonary (Cr, Ni), Renal (Pb, Cd, Hg), Skin (As) and be capable of causing toxicity, respiratory cancer, skin cancer, ulcer, central nervous disorders, heart attack, stroke, proteinuria, osteomalacia etc.

Thus the area of study and research has attracted me to find a suitable and cost effective digestion process of these energy drinks to investigate the heavy metal concentrations. As the young generations of Bangladesh are attracted towards these energy drinks, so to make them safe and aware about the energy drinks constituents this study will be very helpful.

Chapter Two

Materials and Methods

Study Design

A systematic and sequential procedure was performed of the study: it included study area selection, secondary data collection, sampling site selection and energy drinks sample collection, sample preparation for chemical analysis. Energy drinks sample analysis by various instrument, data processing, analysis and interpretation. To determine the heavy metal concentration of energy drinks.

Sample Collection

Twenty-two (22) energy drink samples were collected from Dhaka city and were named as Speed, Power, Oscar, Houston, Braver, Royal Tiger, Wild Brew, Black Horse, Bulldozer, Royal Tiger, Current, Hulk, Hollander, Red Bull, 3 Horses, Bavaria, Shark, Carabao, Effs, Estrella, Royal Eagle and Pure Heaven. The beverages were purchased from various super shops of Dhaka city. After collection, samples were preserved in refrigerator.

Table 1: Sample name, manufacturer and picture.

Serial No.	Sample name	Manufacturer (Country)	Sample picture
01	Speed	Mymensingh Agro Ltd (Bangladesh)	
02	Oscar	Mymensingh Agro Ltd (Bangladesh)	
03	Houston	Akiz Food Bangladesh Limited (Bangladesh)	
04	Power	Mymensingh Agro Ltd (Bangladesh)	
05	Braver	Mymensingh Agro Ltd (Bangladesh)	

06	Royal Tiger	Globe Soft Ltd. (Bangladesh)	
07	Wild Brew	Akiz Food Bangladesh Limited (Bangladesh)	
08	Black horse	Globe Soft Ltd. (Bangladesh)	
09	Bulldozer	Pran Foods Ltd. (Bangladesh)	
10	Royal Tiger	Ast. Bevarages Limited	
11	Current	International Bevarages Private Limited (Coca-cola Company)	
12	Hulk	Sajeeb Group	
13	Hollander	Imported (Germany)	

14	Red bull	Red Bull GmbH (Austria)	
15	3 Horses	Imported (Germany)	
16	Bavaria	Imported (Holland)	
17	Shark	Imported (Thiland)	
18	Royal Eagle	Imported (Spain)	
19	Estrella	Imported (Spain)	
20	Effs	Imported (Turkey)	
21	Carabao	Imported (Thiland)	
22	Pure Heaven	Imported (England)	

Instrumentations

The instruments used in this research project are

- pH meter (Orion 4 star, Thermo-scientific)
- EC meter (EC 214, Hanna instruments)
- TDS measurement machine (SD 320 con, Lovibond)
- Turbidity Meter (TURB 350 IR, WTW)
- Analytical Balance (CP 225 D, Sartorius, Germany)
- Digital Hot plate (Lab Companion, South Korea)
- Muffle Furnace (Memmert, Germany)
- Flame Atomic Absorption Spectrophotometer (SHIMADZU, AA 6800, Japan)
- UV-Visible Spectrophotometer (SHIMADZU, UV 2401PC, Japan)

Sample Preparation

The energy drinks samples were kept open for 24 hours to remove all the CO_2 in it. To prepare the sample for heavy metals analysis 25 mL sample were taken into a beaker and heated the solution at 150ºC for 45 min on a hot plate. Transferred the heated solution to a porcelain crucible and rinse the breaker for several times with a little de-ionized water and it heated again at 150ºC on a hot plate until the sample thickened. Then the crucible was at muffle furnace and heated it at 450 – 550ºC for four (4) hours. When sample became white then stop the heating and after 10mL aqua-regia solution was added in the crucible and transferred the solution into a beaker. It was heated on a hot plate at 90ºC near dryness and it was then cooled down for filtration. The sample was filtered using Whatman 42/44 filter paper and it was mark up to 25 mL in a volumetric flask. This process was repeated for three times for each sample to have an accurate and precise result (**Fig. 2**).

Flame Atomic Absorption Spectrophotometer was used for the determination of Cu, Zn, Pb, Cd, Cr, Ni and Co. UV-Visible Spectrophotometer was used for the analysis of Al, NO_3^-, F^- and PO_4^{3-}. Chloride ion concentration was determined by Argentometric titration method.

Table 2: Operating parameters for FAAS which are used in analysis of metals.

Parameter	Cd	Ni	Cr	Cu	Zn	Co	Pb
Wavelength (nm)	228.8	232.0	357.9	324.8	213.9	240.7	283.3
HCL current (mA)	8.0	12.0	10	6.0	8.0	12	10.0
Acetylene flow rate (L/min)	1.8	1.6	2.2	1.8	2.0	1.6	1.6
Slit (nm)	1.0	0.2	0.5	0.5	0.5	0.2	1.0

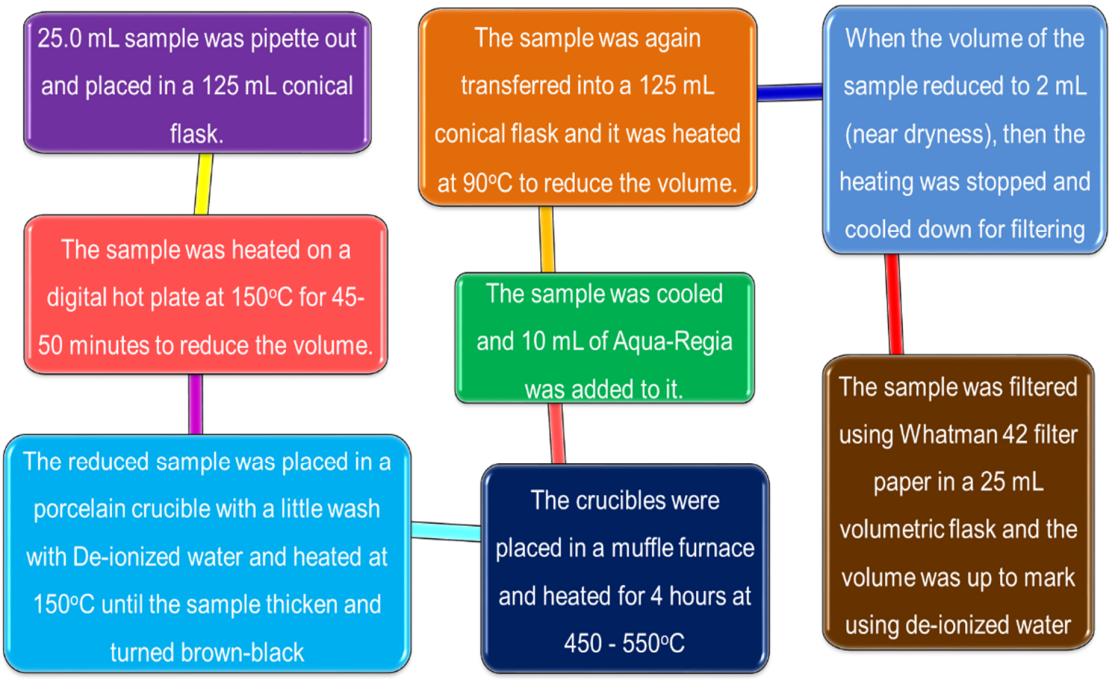

Fig 1: Digestion Method of Energy Drinks

Human Health Risk Assessment

According to the definition of United States Environmental Protection Agency (USEPA), A human health risk assessment is the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future. The Non-carcinogenic (adverse effect on health but not cause cancer) risk assessment can be done by evaluating Chronic Daily Intake (CDI), Hazard Quotient (HQ) and Hazard Index (HI) for Oral Ingestion. The carcinogenic risk is assessed by Cancer Risk (CR) for Oral Ingestion.

Chronic Daily Intake (CDI)

Chronic daily intake or CDI is a measure of the amount of a specific substance in food or drinking water/beverages that can be ingested (orally) on a daily basis over a lifetime without an appreciable health risk. It can be calculated by the equation below and the unit is mg/kg/day.

$$\mathbf{CDI = (C_{ED} \times IR)/ BW}$$

Here, C_{ED} is the heavy metal concentration in energy drinks (mg/L), IR is daily ingestion rate of energy drinks (L/d), BW is the average body weight (kg).

Hazard Quotient (HQ)

The ratio of the potential exposure to a substance and the level at which no adverse effects are expected (calculated as the exposure divided by the appropriate chronic or acute value). A hazard quotient of **1.00** or lower means adverse non cancer effects are unlikely, and thus can be considered to have negligible hazard. According to USEPA (2011), Hazard quotient for oral ingestion for adult can be calculated by the following equation (Masok et al. 2017):

$$HQ_{ing} = \frac{C_{ED} \times IR \times EF \times ED}{AT \times BW \times R_f D_{(oral)}}$$

Oral reference Dose R_fD of **Cu: 0.0371, **Zn**: 0.30, *Co*: 0.01, **Cd**: 0.0005, **Cr**: 0.003, **Ni**: 0.02, **Al**: 1.0, **Pb**: 0.0014, F^-: 0.06 and NO_3^-: 1.60 mg/kg/d.

Exposure Factors	Unit	Values
C_{ED} (Metal concentration in energy drinks)	mg/L	-----
IR (Ingestion Rate)	L/day	0.5
EF (Exposure Frequency)	Day/year	156
ED (Exposure Duration)	Year	30
AT (Average Time)	Days	4680
BW (Average Body Weight)	Kg	70
R_fD (Oral Reference Dose)	mg/kg/d	**

Hazard Index (HI)

The sum of hazard quotients for toxics that affect the same target organ or organ system. The result of HI should be below 1 to avoid adverse effect on health.

$$HI_{ing} = \sum HQ_{ing}$$

Carcinogenic Risk for Oral Ingestion (CR_{ing})

Carcinogenic health risks are expressed by their cancer slope factor (CSF) which converts the estimated exposure through inhalation or ingestion via intake of metals into incremental risk of an individual developing cancer over time. The range of carcinogenic risks (CR_{ing}) acceptable or tolerable is 1.0E-06 to 1.0E-04 (USEPA 2011). The equation is as follows (Iwuanyanwu and Chioma, 2017):

$$CR_{ing} = \frac{C_{ED} \times IR \times EF \times ED \times CSF}{AT \times BW}$$

**Cancer Slope Factor (CSF) for Pb, Cd and Cr is 0.0085, 6.3 and 0.5 mg/kg/day respectively

Exposure Factors	Unit	Values
C_{ED} (Metal concentration in energy drinks)	mg/L	-----
IR (Ingestion Rate)	L/day	0.5
EF (Exposure Frequency)	Day/year	365
ED (Exposure Duration)	Year	70
AT (Average Time)	Days	25,550
BW (Average Body Weight)	Kg	70
CSF (Cancer Slope Factor)	mg/kg/d	**

Chapter 3

Results and Discussion

Results

Several physical and chemical parameters were measured in the collected energy drinks samples. Before the analysis of physical parameters, the samples were open for 24 hours to remove all the dissolved CO_2 in it. The result of physical parameters was tabulated in Table 3 and the heavy metals and anionic contents were shown in Table 4.

Table-3: Physical Parameters of Energy Drinks

Sample ID	Colour	Temp (°C)	pH	EC (µS/cm)	TDS (ppm)	Turbidity (NTU)	TA (%)	Total Sugar Content (g/per serving)
PR	Dark Orange	23.4	**3.027**	414	248.40	**11.49**	0.70	**35.00**
SP	Orange	23.3	**2.930**	466	279.60	**13.47**	0.61	**44.75**
BR	Golden Yellow	23.2	**3.011**	511	332.15	**12.22**	0.23	**38.00**
WB	Light Orange	23.8	**4.041**	534	347.10	**14.25**	0.08	11.25
OS	Light Orange	24.0	**4.031**	820	533.00	**16.23**	0.49	**32.65**
HS	Green	23.7	**2.819**	430	258.00	**13.87**	0.41	**47.88**
BD	Deep Orange	24.0	**3.270**	345	207.00	**10.58**	0.34	**45.96**
BH	Yellow	23.1	**2.944**	573	343.80	**9.34**	0.52	**44.63**
RT	Greenish Yellow	23.5	**3.060**	469	281.40	**11.35**	0.29	**43.07**
RY	Deep Yellow	23.7	**2.502**	563	337.80	**12.73**	0.67	**41.29**
CR	Orange	24.1	**2.586**	339	203.40	**17.24**	0.28	**35.50**
HK	Light Orange	20.9	**3.306**	463	277.80	**22.16**	0.51	**40.97**
TH	Light Yellow	23.4	**4.352**	718	466.70	**25.83**	0.20	9.90
RB	Light Yellow	23.6	**3.483**	1010	707.00	**12.61**	0.78	27.50
HL	Golden Yellow	23.8	**3.872**	1080	756.00	**19.87**	0.70	25.49
BV	Yellow	23.9	**4.197**	876	569.40	**28.22**	0.22	19.79
SH	Golden Yellow	24.6	**3.274**	1900	**1330.00**	**10.87**	0.94	**36.12**
RY	Golden Yellow	24.3	**3.999**	1730	**1211.00**	**24.13**	0.19	12.61

ES	Brown	24.5	**3.623**	699	419.40	**32.20**	0.20	17.65
EF	Golden Brown	23.8	**3.833**	1090	763.00	**36.72**	0.17	15.60
CB	Orange	23.8	**3.458**	2000	**1400.00**	**5.19**	1.01	**43.00**
PH	Deep Brown	24.5	**4.272**	1400	980.00	**33.13**	0.35	**46.86**
Maximum			**4.352**	2000.00	**1400.00**	**36.72**	1.010	**47.88**
Minimum			**2.502**	339.00	203.40	**5.19**	0.080	9.90
Average			**3.450**	837.727	556.91	**17.90**	0.450	**32.32**
WHO Std. (2017)		---	**6.5-8.5**	---	**<1000.0**	**4.00**	**<1.1**	**30 (Average Recommended /day**
BNDWQS (2009)		---	**6.5-8.5**	**<2000.0**	**<1000.0**	**10.00**		

Table 4: Descriptive Statistics of Heavy Metals and Anions in Energy Drinks

Factors	**Maximum**	**Minimum**	**Average**	**SD**	**WHO Std (2017)**	**BNDWQS (2009)**	**USEPA (2009)**
Cu (mg/L)	0.103	0.006	0.051	±0.008	**<2.00**	**<1.00**	**<1.30**
Zn (mg/L)	**6.657**	0.061	1.175	±0.487	**<5.00**		
Ni (mg/L)	**0.180**	0.010	0.070	±0.005	**<0.07**	**<0.10**	**<0.10**
Cd (mg/L)	**0.023**	BDL*	**0.014**	±0.001	**<0.003**	**<0.005**	**<0.005**
Cr (mg/L)	**0.916**	0.012	**0.164**	±0.013	**<0.05**	**<0.05**	**<0.10**
Pb (mg/L)	**0.217**	BDL*	**0.096**	±0.017	**<0.01**	**<0.05**	**<0.015**
Al (mg/L)	**0.128**	0.013	0.050	±0.018	**0.20**		
Co (mg/L)	0.181	0.053	0.118	±0.023	**-----**		
Cl^- (mg/L)	78.460	9.950	39.131	±6.25	**<250.0**	**<600.0**	**<250.0**
F^- (mg/L)	**4.862**	0.240	1.127	±0.569	**<1.50**	**<1.00**	**<4.00**
NO_3^- (mg/L)	**71.940**	BDL*	**30.230**	±10.24	**<50.0**	**<10.0**	**<10.0**
PO_4^{3-} (mg/L)	**32.861**	0.370	**8.409**	±2.65	**---**	**<6.00**	**---**
HCO_3^- (mg/L)	12.227	0.173	3.092	±1.52	**<250.0**	**<600.0**	**---**

BDL: Below Detection Limit. **For NO_3^-, the detection limit was <0.01 mg/L, For Cd <0.005 mg/L, For Pb <0.005 mg/L.**

Non-carcinogenic as well as carcinogenic health risk factors were calculated from the heavy metal concentration and the standards of USEPA 2011. The results were charted in Table 5 and 6 respectively.

Table 5: Hazard Quotient and Hazard Index of Heavy Metals in Energy Drinks

Sample ID	Cu (HQ_{ing})	Zn (HQ_{ing})	Ni (HQ_{ing})	Cd (HQ_{ing})	Cr (HQ_{ing})	Al (HQ_{ing})	Co (HQ_{ing})	Pb (HQ_{ing})	F^- (HQ_{ing})	NO_3^- (HQ_{ing})	HI_{ing} = $\sum HQ_{ing}$
PR	0.012	0.002	0.023	0.186	0.040	0.0009	0.089	0.199	0.277	0.097	0.926
SP	0.016	0.004	0.028	0.286	0.160	0.0006	0.044	0.235	0.184	0.088	**1.044**
BR	0.016	0.003	0.034	0.329	0.100	0.0004	0.041	0.194	0.105	---	0.821
WB	0.020	0.019	0.035	0.271	0.048	0.0002	0.069	---	0.077	0.223	0.761
OS	0.016	0.032	0.027	0.300	0.171	0.0002	0.038	----	0.054	---	0.639
HS	0.008	0.156	0.018	0.214	0.226	0.0001	0.087	---	0.076	0.057	0.842
BD	0.015	0.015	0.021	0.157	0.124	0.0008	0.082	---	0.065	0.093	0.573
BH	0.013	0.007	0.017	0.257	**1.310**	0.0002	0.066	0.066	0.092	0.090	1.918
RT	0.013	0.009	0.015	0.200	0.202	0.0001	0.061	---	0.071	0.114	0.686
RY	0.002	0.011	0.038	---	0.176	0.0001	0.091	**1.107**	0.079	0.169	**1.674**
CR	0.002	0.004	0.033	0.071	0.581	0.0007	0.104	0.740	0.076	0.066	**1.677**
HK	0.004	0.005	0.036	---	0.164	0.0005	0.126	0.872	0.206	0.070	**1.483**
TH	0.016	0.002	0.019	0.143	0.029	0.0002	0.099	0.168	0.103	0.226	0.805
RB	0.016	0.046	0.031	0.171	0.095	0.0003	0.125	0.301	0.102	0.059	0.946
HL	0.016	0.066	0.022	0.114	0.112	0.0002	0.063	0.240	0.029	0.144	0.805
BV	0.014	0.001	0.013	0.229	0.117	0.0002	0.077	---	0.158	0.176	0.785
SH	0.005	0.019	0.037	---	**2.169**	0.0001	0.069	0.505	0.096	---	**2.900**
RY	0.002	0.008	0.013	---	0.081	0.0002	0.085	0.582	0.115	0.255	**1.141**
ES	0.003	0.003	0.011	---	0.086	0.0005	0.129	0.571	0.154	0.291	**1.249**
EF	0.001	0.002	0.008	---	0.305	0.0003	0.089	0.842	0.128	0.224	**1.598**
CB	0.003	0.045	0.064	0.100	0.093	0.0006	0.095	0.806	0.128	0.206	**1.542**
PH	0.003	0.159	0.004	---	**2.181**	0.0003	0.118	0.439	0.579	0.321	**3.803**
HI_{ing} = $\sum HQ_{ing}$	0.217	0.615	0.548	**3.029**	**8.569**	0.008	**1.846**	**7.867**	**2.952**	**2.969**	$\sum HI_{ing}$ = **28.620**

Table 6: Carcinogenic Risk assessment of Cd and Cr in Different Energy Drinks

Sample ID	Cr (CR_{ing})	Cd (CR_{ing})	Pb (CR_{ing})
PR	6.071E-05	5.850E-04	2.368E-06
SP	2.393E-04	9.000E-04	2.793E-06
BR	1.500E-04	1.035E-03	2.307E-06
WB	7.143E-05	8.550E-04	----
OS	2.571E-04	9.450E-04	----
HS	3.393E-04	6.750E-04	----
BD	1.857E-04	4.950E-04	----
BH	1.964E-03	8.100E-04	7.893E-07
RT	3.036E-04	6.300E-04	----

RY	2.643E-04	----	1.318E-05
CR	8.714E-04	2.250E-04	8.804E-06
HK	2.464E-04	----	1.038E-05
TH	4.286E-05	4.500E-04	2.004E-06
RB	1.429E-04	5.400E-04	3.582E-06
HL	1.679E-04	3.600E-04	2.854E-06
BV	1.750E-04	7.200E-04	----
SH	3.254E-03	----	6.011E-06
RY	1.214E-04	----	6.921E-06
ES	1.286E-04	----	6.800E-06
EF	4.571E-04	----	1.002E-05
CB	1.393E-04	3.150E-04	9.593E-06
PH	3.271E-03	----	5.221E-06
Acceptable Limit of CR	**1.0E-06 to 1.0E-04**		

Discussion

From Table 3, the idea of physical state of energy drinks has been found. It is seen that all the energy drinks were colorful beverages with low pH condition. The pH content in all energy drinks were far below than the permissible limit of drinking water standards of WHO and BNDWQS, which is graphically shown in fig 2.

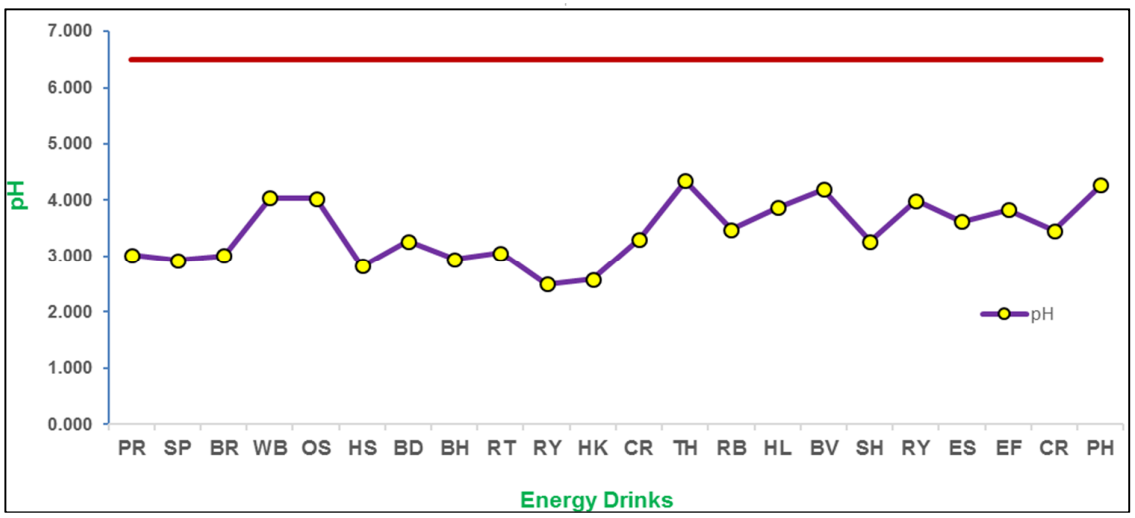

Fig 2: The pH variation of Energy drinks compared by standard

As colored beverage, turbidity of all samples were very high and exceeded the acceptable limit. Total dissolved solid content was also higher in some samples but all other physical factors were found in the acceptable range (Table 3).

The trace element and anion contents in energy drinks were found higher than the different international as well as the national standards. The concentration of Cd, Cr, Ni, NO_3^- and F^- in some samples and Zn, Pb, Al and PO_4^{3-} in few samples were found much higher than the WHO as well as Bangladesh standards. Figure 3, 4 and 5 illustrates the comparison of experimental findings of heavy metals and anions in energy drinks with the standards.

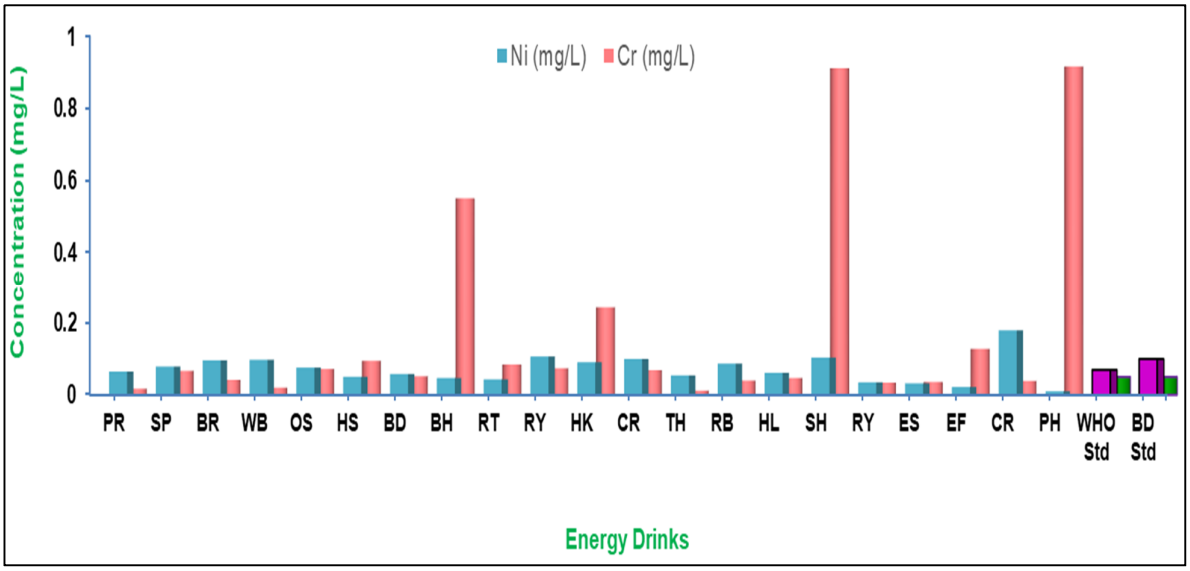

Fig 3: The Ni and Cr concentration of Energy Drinks

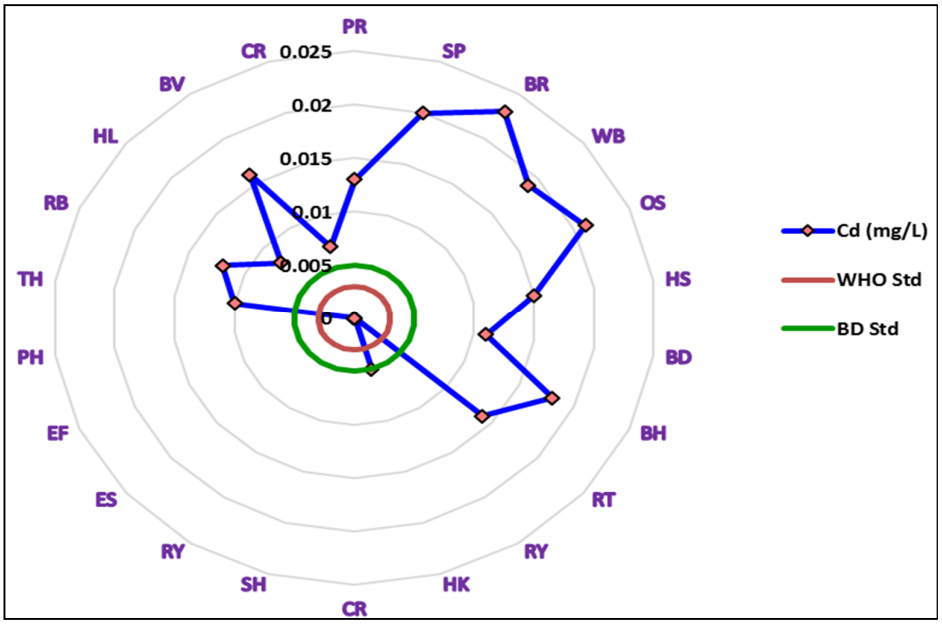

Fig 4: Cd in Energy Drinks and its comparison with standards.

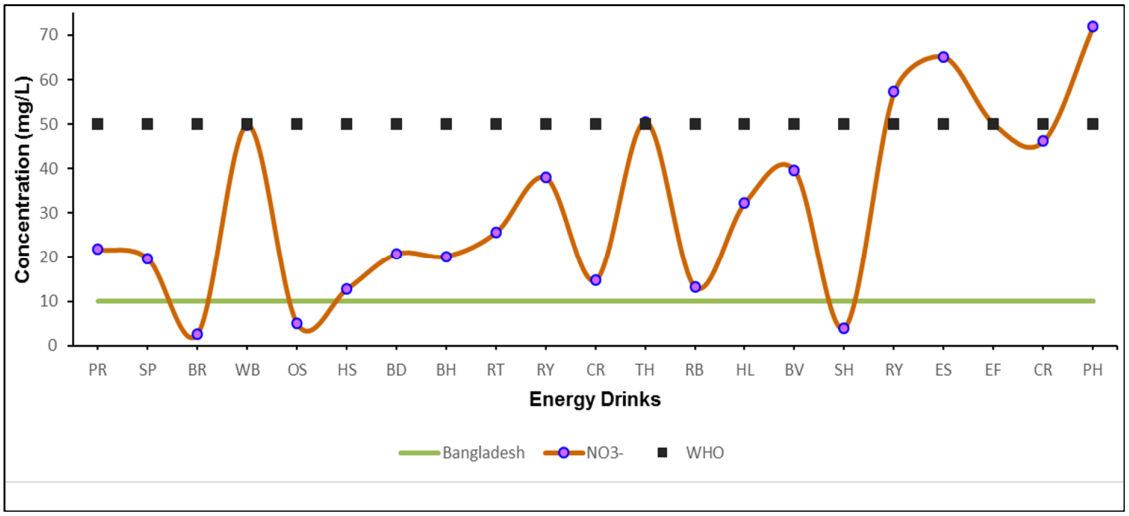

Fig 5: Nitrate ion concentration in energy drinks

The health risk was also evaluated for different heavy metals in energy drinks. There is both non-carcinogenic and carcinogenic risk of these energy drinks due to the presence of heavy metals and anions were in high content. The HQ was almost less than 1 for all metals and anions for all samples. However, Hazard Index of 50% of the samples were found greater than 1.0 which can be alarming. Also, for Cu, Zn, Al and Ni the HI was below 1.0 but greater than 1 for others. Moreover, the total HI was found **28.620** which was extremely higher than the acceptable limit 1.00. The carcinogenic risk of Cd and Cr was also found higher than the permissible range for some samples as well (**Fig. 6**).

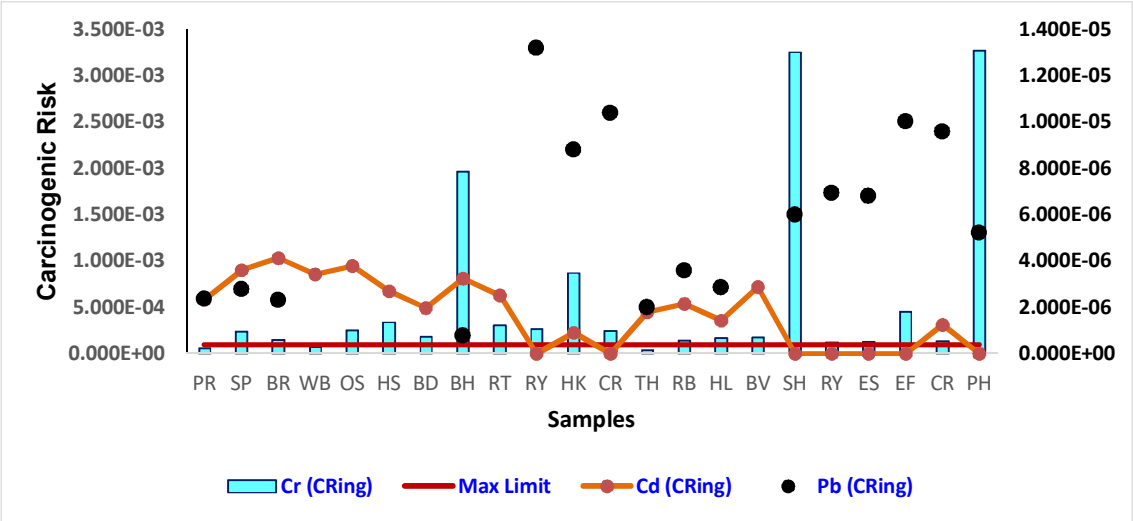

Fig. 6: Carcinogenic Risk Estimation of Energy Drinks

Chapter Four

Conclusion and Recommendations

Conclusion

All the physical parameters like pH, EC, TDS, Turbidity, Total acidity and Total sugar content has been measured and it has been seen that pH of all the energy drinks are relatively very low which is not suitable for our heath, specially our teeth. TDS in some drinks are also higher in some samples indicating the presence of high concentration of metals and other particles. Turbidity of all samples were also higher than the permissible limits due to color and other agents present in it and the total sugar content per serving was also much higher for daily intake for most of the samples. Heavy metals like Cu, Zn, Ni, Cd, Co, Pb and Cr were measured by FAAS and Al, F^-, NO_3^- and PO_4^{3-} was measured by UV-Visible Spectrophotometer. From the study it was found that Cr, Cd, Ni, Pb, F^- and NO_3^- concentration in most of the energy drinks samples were much higher than WHO and BD standard value. All other parameters like EC, Total acidity and the metal concentration like Cu, Zn, Al (except for two sample for Zn and Al) Co, Cl^-, HCO_3^- were found within the limits of both Bangladesh, WHO and USEPA drinking water standards.

For the assessment of non-carcinogenic risk, Chronic Daily Intake (CDI), Hazard Quotient (HQ) and Hazard Index has been evaluated. The HQ of all heavy metals were also below 1 for all samples except one for Pb and three for Cr. The Hazard Index of Cr, Cd, Pb, Co, F^- and NO_3^- were much higher than 1 (8.569, 3.029, 7.867, 1.846, 2.952 and 2.969 respectively). From the HI calculation the increasing non-carcinogenic threat for oral ingestion of energy drinks is BD<OS<RT<WB<BV<TH<HL<BR<HS<PR<RB<SP<RY<ES<CR<CB<EF<RY <HK<BH<SH<PH. The carcinogenic risk factor was also calculated for Pb, Cr and Cd and it was found higher than the standard limit (1×10^{-6} to 1×10^{-4}) for most of the samples for Cd and Cr. This high carcinogenic factor indicates the cancer risk from these drinks for long time of exposure or intake.

Recommendations

- ✓ As energy drinks contain lots of sugar and acid together it caused tooth decay. It occurs by bacteria in the mouth using sugar from drinks and acids that dissolve the enamel and damage the teeth. Regular loss of enamel can lead to cavities and exposure of the inner layers of the tooth that may become sensitive and painful. Each acid attack lasts for around 20 minutes.
- ✓ A straw should be used before drinking energy drinks so that the teeth are less exposed to the sugar and acid in the drink. Also mouth will be rinsed with water immediately after drinking this kind of beverage. Water helps both to neutralize the acid and to increase the production of saliva.

So, these drinks should be taken occasionally, not in a regular basis and if possible in a diluted way to save the teeth as well as the health.

Chapter-5: References

1. Alford C., Cox H. and Wescott R. "The Effects of Red Bull Energy Drink on Human Performance and Mood", Amino Acids, 2001, 21:139-150. http://dx.doi.org/10.1007/s007260170021.
2. Adepoju OT and Ojo VO. "Consumption Pattern of Energy Drinks by University of Ibadan Students and Associated Health Risks Factors", Food and Nutrition Sciences, 2014, 5: 2209-2216. http://dx.doi.org/10.4236/fns.2014.522234.
3. Foran M., Strickland F., Perkins K. and Smith JA. "Excessive Intra operative Bleeding with Chronic Energy Drink Consumption", Journal of Oral & Maxillofacial Surgery, 2012, 70(6): 1439-1441.
4. Van den Eeden SK, Koepsell TD, Longstreth WTJr, van Belle G, Daling JR and McKnight B. "Aspartame ingestion and headaches: A randomized crossover trial", Neurology, 2008, 44:1787– 1793.
5. Millam C., Dass PM., Hanatu T. and Dauda J. "Determination of Physicochemical Parameters, Heavy Metals and Essential Element Concentration in Some Energy Drinks Marked in Jemita Modern Market, Nigeria", FUW Trends in Science & Technology Journal, 2017, 2(2):822–826.
6. Clauson KA, Shields KM, McQueen CE and Persad N. "Safety issues associated with commercially available energy drinks", Journal of the American Pharmacists Association, 2008, 48(3):55-67.
7. Paredes E, Maestre SE, Prats S and Todoli JL, "Simultaneous determination of carbohydrates, carboxylic acids, alcohols, and metals in foods by high-performance liquid chromatography inductively coupled plasma atomic emission spectrometry", Analatical Chemistry, 2006, 78:6774–6782.
8. Mohammed SG, Al-Hashimi AG and Al-Hussainy KS, "Determination of caffeine and trace minerals contents in soft and energy drinks available in Basrah Markets", Pakistan Journal of Nutrition, 2012, 11:747–750.
9. Madeja AS, Welna M and Pohl P, "Determination of elements in energy drinks by ICP OES with minimal sample preparation", Journal of Brazilian Chemical Society, 2013, 24:1606–1612.

10. Hossain MM, Jahan I, Akter S, Hasan MM, Uddin KR, Shawan MMAK, Parvin A, Hasan MA, Ibrahim M and Helali MOH, "Ethanol content in different energy drinks available in Bangladesh", Journal of Biological Science, 2016, 5(2):57-60.
11. Hossain MM, Jahan I, Shawan MMAK, Parvin A, Hasan MMI, Uddin KR, Akter S, Banik S, Hasan MA, Morshed M, Rahman MN and. Rahman SMB "Determination of pH, caffeine and reducing sugar in energy drinks available in Bangladesh", New York Science Journal, 2015, 8(2):92-95.
12. Rath M, "Energy drinks: What is all the hype? The dangers of energy drink consumption", Journal of the American Association of Nurse Practitioners, 2012, 24(2):70-76.
13. Gimba CE, Abechi SE, and Abbas NS, "Studies on Physicochemical Properties, Trace Mineral and Heavy Metal Contents of Common Energy Drinks", International Journal of Advanced Research, 2014, 2(8):131-138.
14. Masok FB, Masiteng PL, Mavunda RD and Maleka PP, "An Integrated Health Risk Evaluation of Toxic Heavy Metals in Water from Richards Bay, South Africa", Journal of Environmental & Analytical Toxicology, 2017, 7(4):1-7, DOI: http://dx.doi.org/10.4172/2161-0525.1000487.
15. Iwuanyanwu KP and Chioma NC, "Evaluation of Heavy Metals Content and Human Health Risk Assessment via Consumption of Vegetables from Selected Markets in Bayelsa State, Nigeria", Biochemistry and Analytical Biochemistry, 2017, 6(3):1-6. DOI: http://dx.doi.org/10.4172/2161-1009.1000332.
16. WHO, "Guidelines for Drinking-water Quality", World Health Organization, 2017, Fourth Ed., ISBN # 978-92-4-154995-0.
17. Department of Public Health Engineering (DPHE), "Water Quality Parameters Bangladesh Standards & WHO Guide Lines", URL: https://old.dphe.gov.bd/index.php?option=com_content&view=article&id=125&Itemid=133 .
18. Bangladesh Bureau of Statistics (BBS), "Bangladesh National Drinking Water Quality Survey of 2009", UNICEF and Bangladesh Bureau of Statistics, 2011, ISBN # 978-984-8969-03-8.
19. US EPA, "National Primary Drinking Water Regulations", United States Environmental Protection Agency, EPA 816-F-09-004, May 2009. URL: https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations.