REDUCTION OF WATER CONTAMINATION, GAS EMISSION AND PRODUCTION OF ENERGY FROM THE WASTE OF DHAKA CITY, BANGLADESH

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Abstract. The current condition of waste management in Dhaka is a clear manifestation of poor sanitation in less developed nations. The city has been experiencing waste dumping on a daily basis. The aim of this research is to minimize waste, eliminate water contamination as well as greenhouse gas (GHG) emission by producing electricity from waste. An experiment was performed on a collection of wastewater samples and it was found that high level of water contamination is brought by extensive waste water contamination. The study found that wastewater from Dhaka city contained a diverse array of chemicals including toxic and non-toxic heavy metals, nitrates, phosphates, sodium (Na^+), potassium (K^+), sodium sulphate (SO_4^{2-}), Calcium (Ca^{2+}), chloride (Cl^-) and harmful polyaromatic hydrocarbons. A multivariate analysis was applied and the level of contamination was detected to exceed the World Health Organization (WHO) permissible limit in all areas. Software simulation was also used in data analysis. The study found that 90% waste collection rate and High tech solid waste incinerator plan could produce 262.125 MW electricity per day and potentially reduce 2.375 million tons GHG emission in total per year.
Keywords: *water quality, green energy, water contamination, organic waste, and wastewater evacuation*

Introduction and literature

Dhaka is the capital of Bangladesh. The city is surrounded by four main rivers along with their many small cannels. Apart from these water masses there are several inland lakes and lowland inside the city. The source of water for these water masses is rain and seasonal rivers. The city population is estimated to be around 19 million hence the city is considered as one of the most highly populated towns on Earth. Moreover, the city is known to produce tremendous amount of solid wastes on a daily basis. Rising waste volumes together with the increasing complexity of waste treatment have become not only a major and growing public health but also environmental concerns. Due to the population growth, changing lifestyle and spending sequence of individuals, the amount of waste production is ever growing. The eminence as well as the composition of wastes are varying radically. Water pollution is not only impacting water organisms alone but also damages the natural biodiversity.

From the map (*Fig. 1*) we can see rivers around Dhaka City. These water-bodies are highly polluted and have reached alarming levels of pollution that is both economic and health concerns to inhabitants, mainly to the less endowed in the city. Generally, consumption of water originated from several of sources such as rivers, lakes and ponds and ground water. These waters are contaminated with arsenic (As), a toxic metalloid.

Arsenic exists in inorganic form (As^{3+} and As^{5+}) in aquatic system and poses a large public health threat when combined with methyl and dimethyl arsenic composites from natural systems including, anthropogenic as well as ecological sources (Chatterji, Arlosoroff and Guha, 2017; Cordonet al., 2018; Cui et al., 2018; Ijumulana et al., 2016). Comparative studies have shown that arsenic in water causes health risks such as generating non cancer effects, hypertension, cardiovascular diseases and diabetes (Tripathee et al., 2016; Khuhawar et al., 2019; Kumar et al., 2015; Song et al., 2016; Ijumulana et al., 2016). Inorganic arsenicals which fall in group I carcinogens create a high health risk which claims about 60–100 million people in India and Bangladesh after being found in drinking water as major contaminant from river, canal and lake (Huang et al., 2016; Antoniadis et al., 2017; Bettoschi et al., 2018). UNICEF has reported high awareness in Arsenic contamination in various parts in the country (Mehrotra et al., 2016; Ur Rehman et al., 2018).
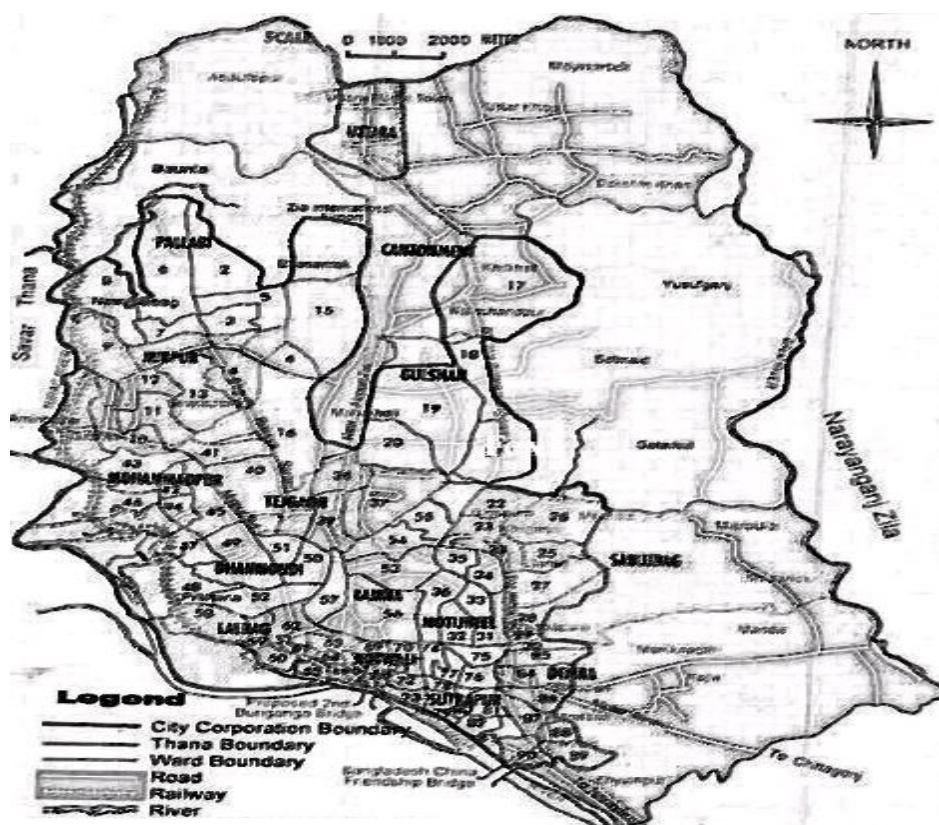

Figure 1. Dhaka City location map

This arsenic contamination happened due to household solid wastes, wastes from small industries and tannery effluents with multifarious features. The wastes are also linked with high level of organic pollutants mainly made up of chemicals as well as significant amounts of inorganic components which are toxic together which cause inhibitory effects on biological system (Ouyang et al., 2018 and Mohammadi et al., 2015). The water sources are polluted with more than 138 different pollutants. In addition, inhabitants are also throwing wastes directly and indirectly into the rivers. The biggest sources are Hazaribagh tannery wastes; water containing COD and the toxic stench wafting throughout the whole area is almost suffocating. Based on the current

statistics lack of waste management in the city is turning out to be the main cause of water pollution. During the rainy season wastes and wastewater production is 100% higher than in the dry season.

The main supply of water in the city is (83%) ground water and surface water (17%). The peripheral rivers have undergone major pollution due to indiscriminate discharge of domestic and industrial wastes (*Figs. 2–5*). As a result, surface and ground waters are highly contaminated by different types of chemicals and microbes. Some other identified contaminants are residual chlorine, coliform and faecal coliform. According to Dhaka Water Supply and Sewerage Authority (DWASA, 2013), the city experiences high concentrations of E. coli in the ground water in the downtown area while water supply is also contaminated.

Figure 2. Waste mixing with rain water at primary collection area

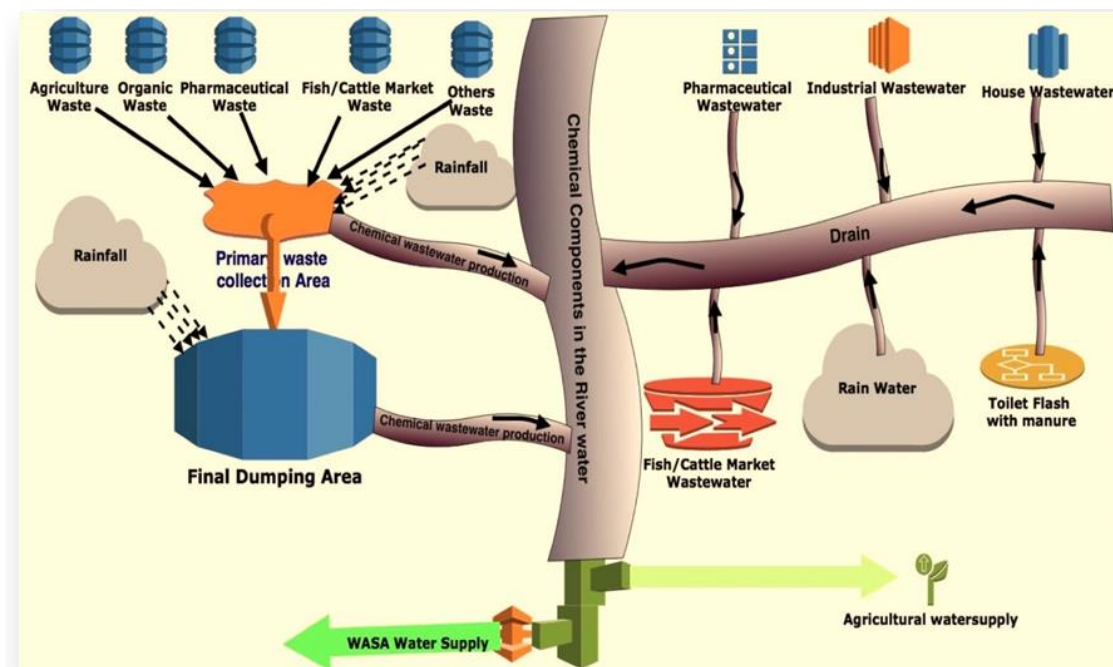*Figure 3. Bank of the river final dumping site*

Figure 4. Waste water generation process
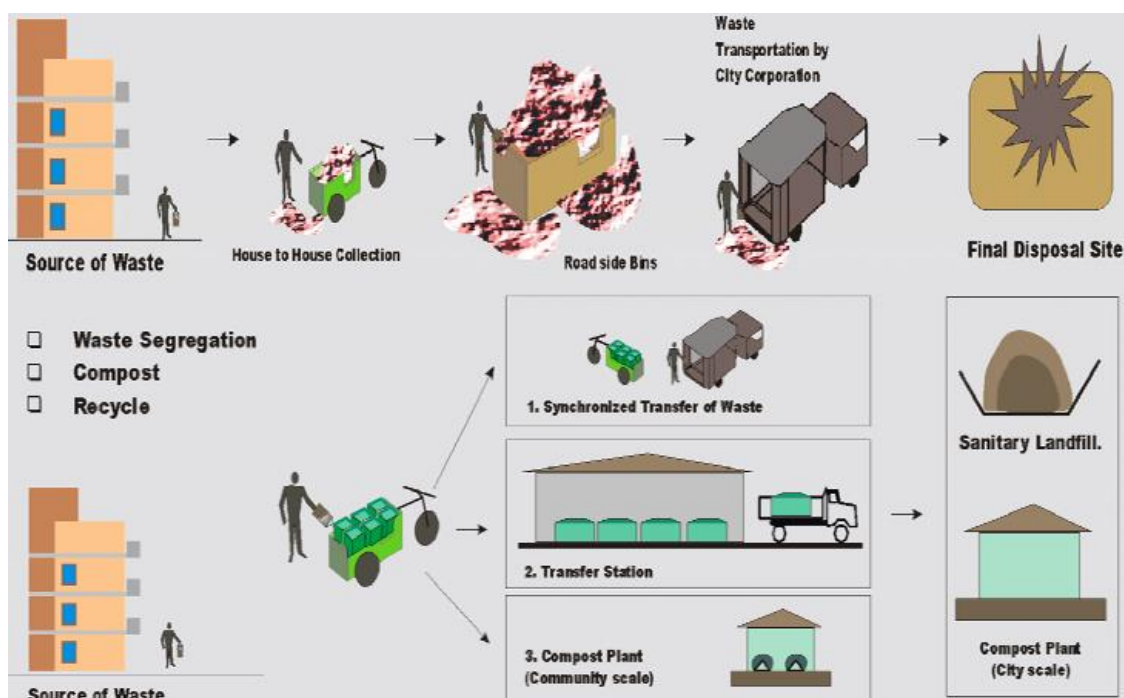
Figure 5. Traditional waste management system in Dhaka City

The fact that untreated industrial wastes are playing a critical role in the degradation of the environment, it is yet to receive international recognition. The poor in the city are highly affected by the pollution based on the current report. The city watershed has reduced by more than 30% over the past decade (Ana and Nandini, 2009). Ground water level is rapidly declining 3 m/yr (DWASA, 2013) due to a large-scale abstraction.

Therefore, ground water is no longer a viable option for water supply and the surface water will be the only option for water sources within the next half-century. To address the tremendous water pollution problem, specialists ought to independently collect as well as treat wastes in order to save the surface and the ground waters.

Currently there is no government agency which has carried out research concerning this on-going environmental issue. There is a great need for arsenic assessment study in the area to establish the level of waste and water pollution in the city of Dhaka (Bangladesh) as well as to assess the level of pollution and the main cause of pollution. The paper also sought to determine water quality parameter such as temperature, pH as well as other parameters in the water sources. In this outline, the objectives of the study were the followings: to show how wastes are converted to wastewater and mix with the water body (*Figure 4)*; to use a high tech advance waste management system in Dhaka City and to show GHG emission load reduction in order to save the valuable water resources.

Materials and methods

Study area

The study was conducted in Dhaka City. Dhaka is situated at 23°42'58"N 90°23'46"E on the eastern bank of the Buriganga River as shown in *Figure 1*.

Water sampling and analysis

Primary data was collected through sampling method and later on analysed independently based on the water sample origin. Water samples were collected from Buriganga River, Balu River, Turag River and in Tongi Canal around Dhaka City. Wastewater from tannery examined in the study was sourced from various sites such as Hazaribagh. Over 200 larger tanneries as well as other small ones collectively made up the largest fraction of wastewaters in the city. Grab samples collected from different drain tanneries were assessed to determine the conventional characterization of the raw tannery wastewater in the area. The recommended analyses were carried out in pair in accordance with required standard methods (Clessceri et al., 1998). More than 256 water samples from various sources were taken independently and from separate sampling points within Buriganga River, Balu River, Turag River and in Tongi Canal at Dhaka City. Of all collected water samples more than 153 were taken from > 15 m depth while the same number were taken from surface water. Van Dorn plastic bottles were used to gather samples. The collected water samples were stored in plastic bottles that were previously soaked in 10% nitric acid. During the study period, the researcher assessed water temperature, its pH as well as the concentration of dissolved solids using various instruments such as thermometer, pH meter respectively. The samples which were previously collected were then stored in an ice box, and transported to the lab in the same day to avoid delay.

A dilution of 1000 mg recommended standard solutions were sourced from internationally certified lab to be used as a control in the study of the various metals. In order to prevent contamination of the samples, all the glassware and plastic containers were treated with 5M HNO_3 and rinsed with distilled water and completely with ultrapure water. The physicochemical levels were established using recommended techniques (Tamasi and Cini, 2004; APHA, 1998). Moreover, methyl-orange was used to assess the level of alkalinity in the sample waters. EDTA was used to measure Calcium concentration in the

samples using of complexometric titration (Eaton et al., 1995). In respect to analysis of arsenic as well as other metals water samples were pre-concentrated different zones (Arain et al., 2007; AOAC, 1995). Saturation indices were measured using speciation-modeling to determine the equilibrium condition of the minerals in the samples (USGS, 2007).

Filtered samples of aliquot were measured by evaporation method to estimate the amount of dissolved solid in the water samples. Both Sodium (Na) and Potassium (K) were determined using flame-photometer while Calcium (Ca) and Magnesium (Mg) were examined by complexometric titration technique using Na_2 EDTA as titrant. Other cations such as Fe^{2+}, Fe^{3+}, Mn^{2+}, Cu^{2+}, Zn^{2+}, B^{3-}, together with anions such as Cl^-, NO_3^--N, SO_4^{2-}-S, HCO_3^-, and CO_3^{2-} were examined based on recommended procedures. Qualitative test was done to detect the presence or absence of Arsenic (As). Irrigated water quality parameters viz. SAR, SSP, and H_T were used to classify the suitability of waters, along with pH, EC, and TDS.

For both quality assurance and control (QA/QC), data were examined based on the recommended method (Zacheus and Martikainen, 1997). Flame atomic absorption spectrophotometer technique was used to examine sodium, iron, and potassium within given limits of 0.02 g LOD. Consequently, sulphate concentration together with chloride, as well as nitrate concentrations were assessed using LOD 1.2, 1.4, 1.5 and 2.7 g, in that order. For the purpose of validation of ions, the researcher carried out ionic balance test (Lopez et al., 1999) as

$$Ion\ balance\ percent = \left\{ \frac{\Sigma_{cations} - \Sigma_{anions}}{\Sigma_{cations} + \Sigma_{anions}} \right\} \times 100 \qquad (Eq.1)$$

On average the ion balance was around 1.18% with two outliers of around 1.8% and −3.1% were determined, the mean of the ion balance was around 0.6% (*Table 1*). The parameters of SAR, SSP, and H_T were measured from the analyzed data using the following formula:

$$SAR = \frac{[Na^+]}{\left\{ \frac{([Ca^{2+}] + [Mg^{2+}])}{2} \right\} \ \frac{1}{2}} \qquad (Eq.2)$$

$$SSP = \frac{Soluble\ Na\ concentration\ (meL^{-1})}{Total\ cation\ concentration\ (meL^{-1})} \times 100 \qquad (Eq.3)$$

$$H_T (mgL^{-1}) = 2.5 \times Ca^{2+} + 4.1 \times Mg^{2+} \qquad (Eq.4)$$

Correlation coefficient analysis was done for all possible combinations within the quality parameter.

Waste sample analysis

Primary and secondary data were used for this study purpose. Secondary data was collected through various books, reports, journals and articles, such as JAICA, Ministry of Environment and Forest (MOEF), Dhaka City Corporation (DCC) reports and different waste management plants in Japan. Data collection methods included document/literature review, semi-structured interviews, checklists and observation.

Table 1a. *The mean values of physic-chemical parameters and arsenic concentration in ground water from Dhaka District, Bangladesh*

Sample ID	T (°C)	pH	EC (mS cm^{-1})	As (µg)	TDS (mg)	Ca2$^+$ (mg)	Mg2$^+$ (mg)	Na$^+$ (mg)	K$^+$ (mg)	HCO$_3$$^{2-}$ (mg)	Cl$^-$ (mg)	NO$_2$$^-$ (mg)	NO$_3$$^-$ (mg)	SO$_4$$^{2-}$ (mg)	Fe (mg)
PS1	29.2	8.3	2.39	83.01	1148	219	49.3	755	43	1360	233	2.43	25	1017	4.01
PS2	27.3	7.1	1.7	14.01	783	168	26.3	653	9.1	967	267	1.39	12.3	709	0.26
PS3	28.5	8.9	4.15	108.0	1951	299	99.6	801	18.8	355	646	4.23	47.9	1519	4.29
PS4	26.1	7.1	3.93	15.31	1846	79.1	35.1	526	55.9	219	419	2.35	41.3	723	0.21
PS5	28.5	9.0	2.99	55.13	1396	102	63.8	946	52.7	537	718	1.58	27.5	1050	0.10
PS6	29.3	8.3	1.97	26.3	911	87.7	42.3	532	17.5	221	347	0.56	13.1	830	1.11
PS7	26.4	7.8	0.88	31.2	490	34.5	40.3	368	14.4	270	236	3.47	6.1	467	0.53
PS8	26.1	7.7	1.65	57.1	720	37.7	11.6	239	6.9	178	179	1.03	13.2	248	0.09
PS9	27,2	7.9	2.41	4.03	897	38.4	26.7	201	4.3	271	198	0.97	1.3	110	0.10
PS10	31.0	7.1	4.56	20.2	298	110.5	57.2	737	10.1	521	523	0.94	26.5	907	0.63
PS11	30.3	7.6	1.11	54.3	881	50	21.3	749	8.3	311	521	7.55	12.4	782	0.21
PS12	30.1	7.9	1.09	27.1	2227	89.1	27.9	561	17.3	337	293	1.22	12.3	881	0.60
PS13	29.4	8.0	1.01	55.2	523	55.5	18.1	598	13.1	287	278	0.93	9.7	411	0.20
PS14	28.5	8.1	2.53	45.1	497	38.7	68.3	297	17.9	279	203	2.53	12.9	333	0.20
PS15	27.4	7.6	0.49	43.13	433	231.2	23.3	321	14.0	513	513	2.23	11.9	1107	0.59
PS16	28.3	7.2	2.79	57.9	1253	243.5	25.3	633	4.0	304	464	2.71	25.6	1122	0.42
PS17	27.1	7.9	0.49	29.1	205	124.3	21.9	541	10.5	287	232	0.49	6.0	978	0.43
PS18	29.3	8.1	0.75	13.3	271	43.7	2.9	501	9.1	451	163	0.67	24.9	317	0.59
PS19	31.4	8	1.11	20.1	521	78.5	17	489	11.1	449	232	0.49	7.1	563	0.32
DTS1	32.3	7.9	1.13	37.2	347	71.3	82.5	339	8.2	320	193	0.99	6.1	452	0.14
DTS2	35.9	8.0	1.09	45.9	489	52.1	27.1	417	7.2	330	227	1.65	6.2	367	0.32
DTS3	28.1	7.6	1.13	66.1	543	59.5	21.7	397	7.9	220	143	0.97	0.9	723	0.23
DTS4	32.4	7.8	1.19	36.2	649	41.3	28.9	247	6.1	320	291	0.20	12.5	477	02.1
DTS5	25.1	8.1	1.16	44.9	621	61.1	21.1	241	7.1	230	130	0.30	0.8	366	0.50
DTS6	32.2	7.9	1.11	36.1	679	42.1	28	397	5.2	209	197	1.67	12.9	631	0.33

PS: pump sample, DTS: deep tube well sample

Table 1b. *The mean values of physic-chemical parameters and arsenic concentration in surface water from Dhaka District, Bangladesh*

Sample ID	T (°C)	pH	EC (mS cm^{-1})	As (µg)	TDS (mg)	Ca^{2+} (mg)	Mg^{2+} (mg)	Na$^+$ (mg)	K$^+$ (mg)	HCO$_3^{2-}$ (mg)	Cl$^-$ (mg)	NO$_2^-$ (mg)	NO$_3^-$ (mg)	SO$_4^{2-}$ (mg)	Fe (mg)
RS1	21.2	7.3	0.42	3.01	189	25.9	13.3	223	4.2	180	163	0.43	6.5	247	0.09
RS2	22.3	7.1	0.40	4.01	183	8.3	8.3	215	2.9	287	117	0.49	6.3	109	0.12
RS3	23.5	7.9	2.67	38.0	251	86.1	39.6	709	18.9	345	156	1.03	17.9	1239	0.39
MS1	22.1	7.1	0.43	5.31	186	40.1	15.1	239	5.9	249	179	0.53	6.3	196	0.21
MS2	21.5	7.0	0.40	5.13	256	13.2	8.1	183	6.7	271	68	1.58	5.9	117	0.10
MS3	22.3	8.3	1.84	16.3	211	51.7	21.1	465	17.9	231	272	0.56	16.1	613	0.11
MS4	22.4	7.0	0.47	6.31	190	16.5	5.5	243	7.6	210	186	1.13	6.1	187	0.13
MS5	23.1	7.6	1.69	50.1	220	224.7	36.9	483	15.9	278	359	0.53	13.1	988	0.09
MS6	25.2	7.1	0.46	4.03	197	12.4	9.5	211	5.3	201	178	0.97	6.9	130	0.10
MS7	22.5	7.9	3.62	5.91	198	25.5	12.3	227	12.1	191	173	0.54	16.5	207	0.03
MS8	23.3	7.2	0.41	5.01	211	6.3	23.6	271	35.1	201	333	0.55	6.4	162	0.11
MS9	24.1	7.1	0.49	4.33	207	23.1	17.9	239	7.3	197	223	0.62	14.3	181	0.15
MS10	22.4	7.0	0.50	11.02	230	17.5	18.1	213	15.1	187	208	0.73	4.9	241	0.13
MS11	23.5	7.1	0.53	7.91	197	18.7	11.3	357	43.1	479	243	2.83	73.9	263	0.29
MS12	23.4	7.5	0.40	17.13	233	11.2	33.3	401	15.1	173	283	1.53	11.9	597	0.11
MS13	22.3	7.2	0.49	6.09	253	33.5	3.3	333	45.7	164	244	1.11	0.8	352	0.12
MS14	22.1	7.1	3.71	6.11	215	22.3	11.9	241	14.5	157	282	0.59	0.4	207	0.03
MS15	23.3	7.5	0.55	5.23	171	82.1	2.9	251	10.1	151	243	3.17	48.9	217	0.29
MS16	22.4	7.8	3.49	11.21	121	22.5	45.5	539	7.2	149	235	1.29	13.1	893	0.02
MS17	23.3	7.6	1.44	11.2	247	81.3	25.5	439	25.1	123	196	1.59	14.1	622	0.14
MS18	24.9	8.0	3.27	7.99	169	32.1	7.1	327	14.2	134	317	1.50	3.2	207	0.12
MS19	22.1	8.6	0.91	8.2	243	15.5	10.7	139	9.1	118	63	0.87	33.1	243	0.13
MS20	23.4	7.5	0.34	6.09	149	42.3	8.9	297	6.1	119	231	0.50	12.5	227	0.11

A semi-structured interview refers to a gathering in which the interviewer asks open-ended questions and allows for a discussion with the interviewee. There is no formalized process which is used while asking or answering the questions. In most cases, the interviewer asks the general questions which lead to further short questions within the discussion.

A checklist structures an individual's evaluation or observation of performance or even an artifact. They use simple criteria which can be labelled as present or absent and provide space for the observer to comment. Checklist can also be used to evaluate a database or structure out a peer observation and guide well while collecting data from a sample of the population.

The measure of combined dissolved solids in waters were determined by evaporating the filtrate of filtered samples. Sodium and Potassium levels were obtained by flame-photometer where else Calcium and Magnesium were obtained through complexometric titration using Na_2EDTA as reference sample titrant. Cations like Cu^{2+}, Zn^{2+}, and anions like Cl^-, NO_3^--N, SO_4^{2-}-S, HCO_3^-, and CO_3^{2-} were measured through photometry. The presence or absence of Arsenic (As) metal was determined using qualitative test.

The cation levels were obtained by atomic spectrophotometry by mechanism of flame absorption for potassium, sodium and iron while for the other cations hydride generation was used in their spectrophotometry. Anion concentrations were obtained through ion chromatography (Metrohm 838) and validated then calculated using *Equation 1*.

Lastly, observation involved direct or indirect viewing of object whether aware or unaware if it is being observed. In observation, the researcher may choose to collect data through a set of time periods or progressive observation throughout the project.

To properly investigate on waste generation (*Fig. 4*) and disposal system (*Fig. 2,3 & 5*), some areas were selected as sampling areas, such as Hazaribagh located at 23.734722°N, 90.369444°E with a total area of around 3.58 km^2; Gabtoli situated at 24°53'N 89° 27'E; Uttara on the other hand is situated at 23° 52'N 90°24.3'E; Dholpur (23.71674°N 90.4323178°E) and Mirpur located at 23.809309°N 90.360928°E. Stratified random sampling technique was used for public opinion survey on some attributes, such as waste generation (*Fig. 4*), waste dumping (*Fig. 2,&3*), and waste safety. The analysis was done using Urban Co-benefits Evaluation Tools and statistical tools, like Microsoft Excel used to perform calculation, visualization and analysis of data and information. It aids researchers to structure and process data through utilization of rows, columns and a combination of different formulas.

The method was to determine whether the current waste management process (*Fig. 5*) was being done as per legislation, the frequency in which environmental harm occurs and its significance. These measures were put in place to verify environmental damages (*Fig. 3*) and the optimal usage of water, energy and natural resources. In the project we have done the software simulation by classifying the wastes where combustible and non-combustible items are separated from the beginning. Step by step waste generation (*Fig. 4*), collection separation processes were done. Only the combustible wastes are simulated by the software. Hopefully, some medical wastes were also included in this system because in Dhaka City all

wastes are dumped in the open pit and one dumping site. The aim was to answer the questions of this study which were: (1) how wastes convert to a wastewater stream, (2) chemical pollutants confirmation, (3) greenhouse gases production by conventional waste management procedure, and (4) a solution for saving surface water and GHG reduction

Total energy in MSW

Total energy in MSW was determined by its composition and moisture content. The MSW was reported to produce 95 m^3 of methane gas per tonne with an efficiency of 80% and energy production of $12.98 \cdot 10^5$ KWh/year (Kumar et al., 2009). The energy content of waste was measured by bomb calorimeter which entailed total combustion of the sample and then gauging the heat rise in surrounding water bath (Masters and Ela, 2013). This temperature value obtained is mainly higher in industries which manufacture products such as paper, metal and plastics. Khan et al. (1919) formulated formulas that determine temperature in food and paper industries. This formula was expressed in the equation below:

$$\text{HHV}\left(\frac{\text{kJ}}{\text{kg}}\right) = 53.5(f + 3.6cp) + 372plr \qquad (Eq.5)$$

where f is food, cp is paper and cardboard, and plr is plastic. However, some amount of HHV energy is lost through vaporization of the moisture.

Results

The results for the study were as follows:

Test results (water sample)

The tests were carried out in water samples in two depths; groundwater water and surface water. The ground water samples were classified depending on the mode they are found. Pump samples (PS, $n = 113$) were obtained at a depth range of 15.85 to 33.5 m and deep-tube well samples (DTS, $n = 40$) were obtained at a depth variation up to 120 m depth as shown in *Table 1a*. Surface water samples were classified into two categories, namely river samples (RS, $n = 33$) and municipal samples (MS, $n = 120$), depending on the place the samples were obtained from. Physical and chemical analysis of all samples were done.

The pH and EC of all samples were measured and their range obtained. The pH range for PS was 7.1-9.0 while for DTS was 7.9-8.1. The EC range for groundwater samples were 0.49–4.56 mS cm^{-1} for PS and 1.09–1.10 mS cm^{-1} for DTS. Alkalinity ranged from 178–1360 mg for both groundwater samples. The pH range for RS was 7.1-7.9 while that of MS was 7.0-8.6 where else the EC values ranged from 0.40–2.67 mS cm^{-1} and 0.40–3.71 mS cm^{-1}, respectively. Alkalinity in both samples of surface water ranged from 118–479 mg. The composition of major ion was almost similar in both categories of surface water.

Groundwater had significant Fe concentration ranging from 0.1 to 4.01 mg while surface water the level ranged much below the WHO recommendable range except at sampling point RS3. Arsenic concentration was more in the groundwater

compared to surface water with ground water registering the highest level of 108 g compared to 50.1 g for surface water.

Simulation results

The simulation result is shown in *Figures 6–8*. *Figure 6* shows almost 49% for landfill and open burning is almost 12%. *Figures 7* and *8* show that greenhouse gas emission is extremely high level in conventional approach.
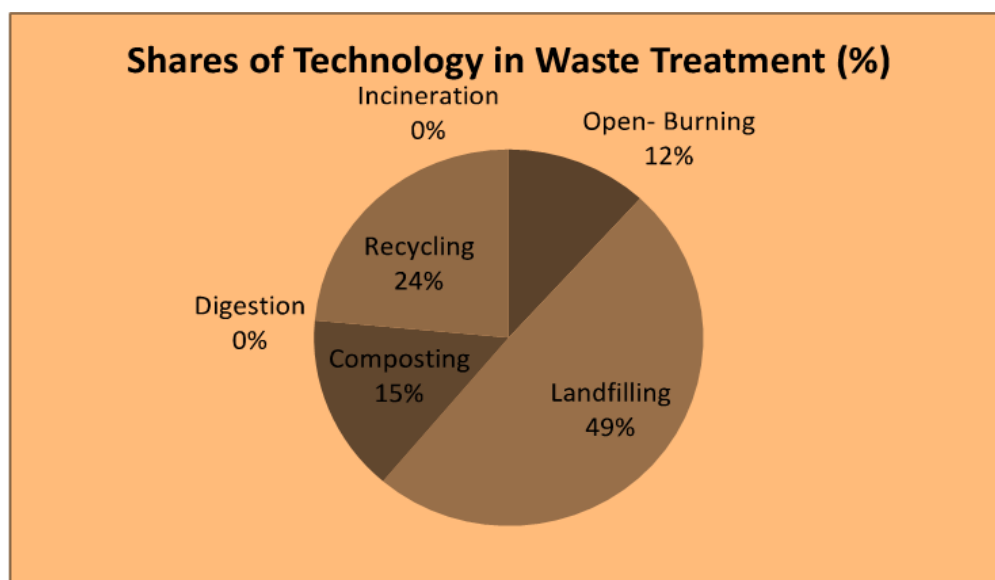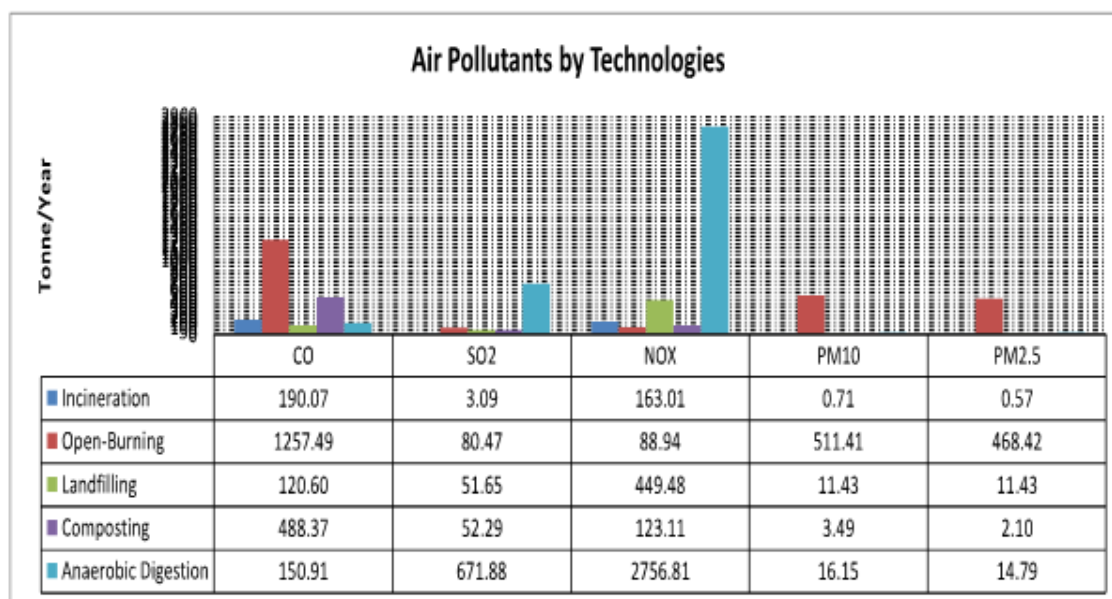

Figure 6. *Current waste dumping*

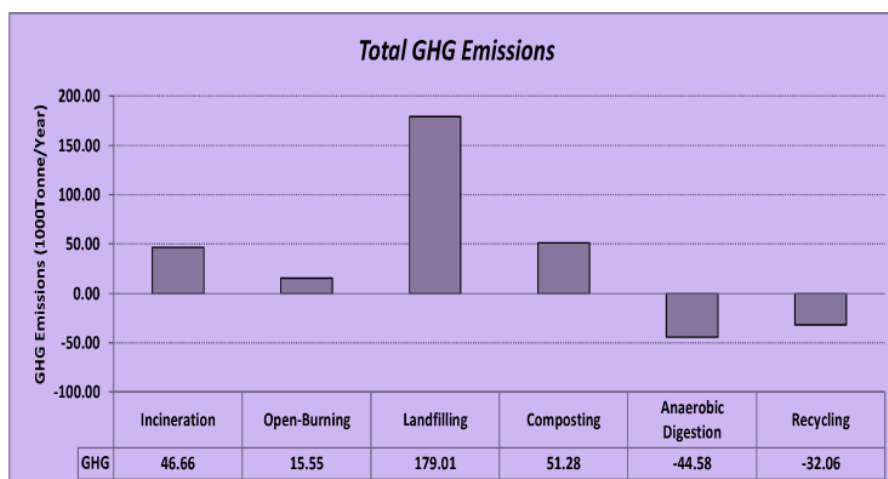|	CO	SO2	NOX	PM10	PM2.5
■ Incineration	190.07	3.09	163.01	0.71	0.57
■ Open-Burning	1257.49	80.47	88.94	511.41	468.42
■ Landfilling	120.60	51.65	449.48	11.43	11.43
■ Composting	488.37	52.29	123.11	3.49	2.10
■ Anaerobic Digestion	150.91	671.88	2756.81	16.15	14.79

Figure 7. *Current GHG emission*

Figure 8. *Current air pollution*

Discussion

The pH of all samples was nearly above the acceptable level of World Health Organization (WHO) with high level of EC and alkalinity in samples which were obtained at deep points ($p > 0.05$). This variation in the levels of pH and alkalinity in groundwater samples compared to surface water samples was due to excess dissolution of organic and inorganic compounds which sediment at the ground of the water as thousands of tonnes of wastes are produced during the wet season (*Fig. 2*). Due to lack of proper treatment, wastes are terminated to the final dumping areas (*Fig. 3*) or open pits in main streets or close to the city emitting GHG gases which are dissolved in water by rainwater or seasonal water creating more anions in the surface of the water (*Fig. 2*), and finally the wastewaters are flowing into the rivers (*Fig. 3*). In the study the large concentration of cations and anions were due to more solubility of GHG gases emitted upon the burning of large quantities of waste production within the city. There was similar concentration of major ion in both municipal treated water samples and river surface water due to even distribution of ions in the water at a similar depth. There was a relative range in levels of different cations and anions. Sulphate (SO_4^{2-}) ions ranged from 109–1519 mg, chloride Cl^- ions ranging from 63 to 718 mg, while Sodium ions (Na^+) ranged from 139 to 946 mg. Calcium ions ranged from 6.3 to 299 mg. The levels of concentration of different cations and anions depended on the nature of waste being dumped openly in the pit and their solubility levels in water (*Fig. 3*).

This 3R approach in stimulant results is very good (*Fig. 5*). However, this approach has its limitation, it can cover only small amount of wastes per day. To tackle huge amount of wastes (12-15 thousand tons/day) that produced in Dhaka City, it is not an ideal approach. In this situation, we are proposing an advanced technology for waste management system that could cover all the wastes in Dhaka City.

Proposed technology

Waste life cycle

After reviewing the waste disposal system and 3R approach (*Fig. 5*) in Dhaka City, we propose a design for waste life cycle to achieve our final goal. *Figure 9* shows the

proposed life cycle for solid wastes where waste-classification is started at sources (Burnable, non-burnable, recyclable, organic particularly kitchen wastes) and each of the waste will be treated accordingly.
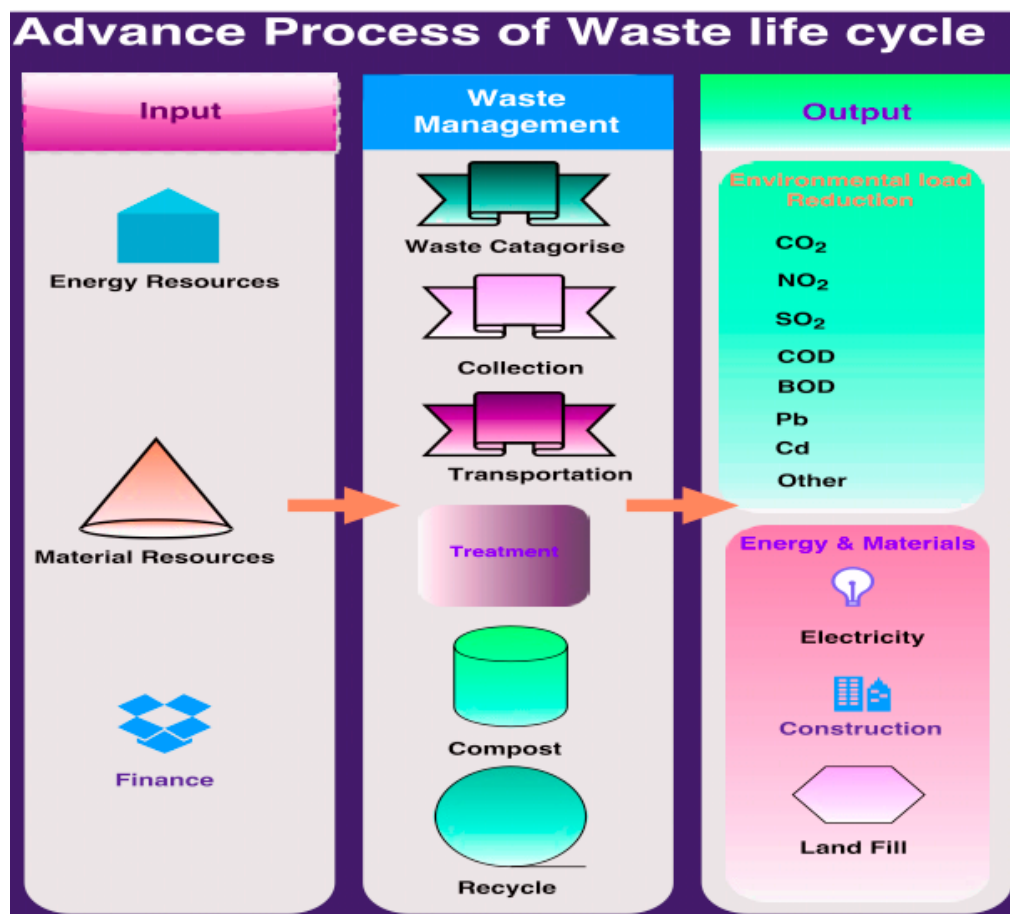

Figure 9. Proposed system

Proposed treatment plant

Figure 10 depicts incineration structure where burnable wastes are burned at 500 to 600 °C to keep valuable aluminium and un-oxidised ferrous metal that can be recovered by recycling. Non-combustible materials and sand are discharged from the bottom of the furnace through the non-combustible discharge conveyor. There are two types of separators here. If there are any ferrous metals contained in the non-combustible these are recovered with a magnetic separator, and the aluminium is recovered with an aluminium separator. The sand is stored in the sand storage tank.

Second stage is ash melting. The ash melting furnace has higher temperature because the gas is combusted while being circulated at the relatively high temperature at 1300 to 1400 °C (Kurahama Sanitary Facilities Association, Japan). This high temperature melts the ash contained in the gas, turning it into the slag, while greatly decreasing the amount of generated dioxins. The bottom of the ash-melting furnace is a discharge system for slag. Slag scraper conveyor is keeping and cooling slag by circulating cool water. This water is cooled by the water cooler and recycled for slag cooling system. Finally, slag is crushed by the slag crusher and stored in the slag storage yard.
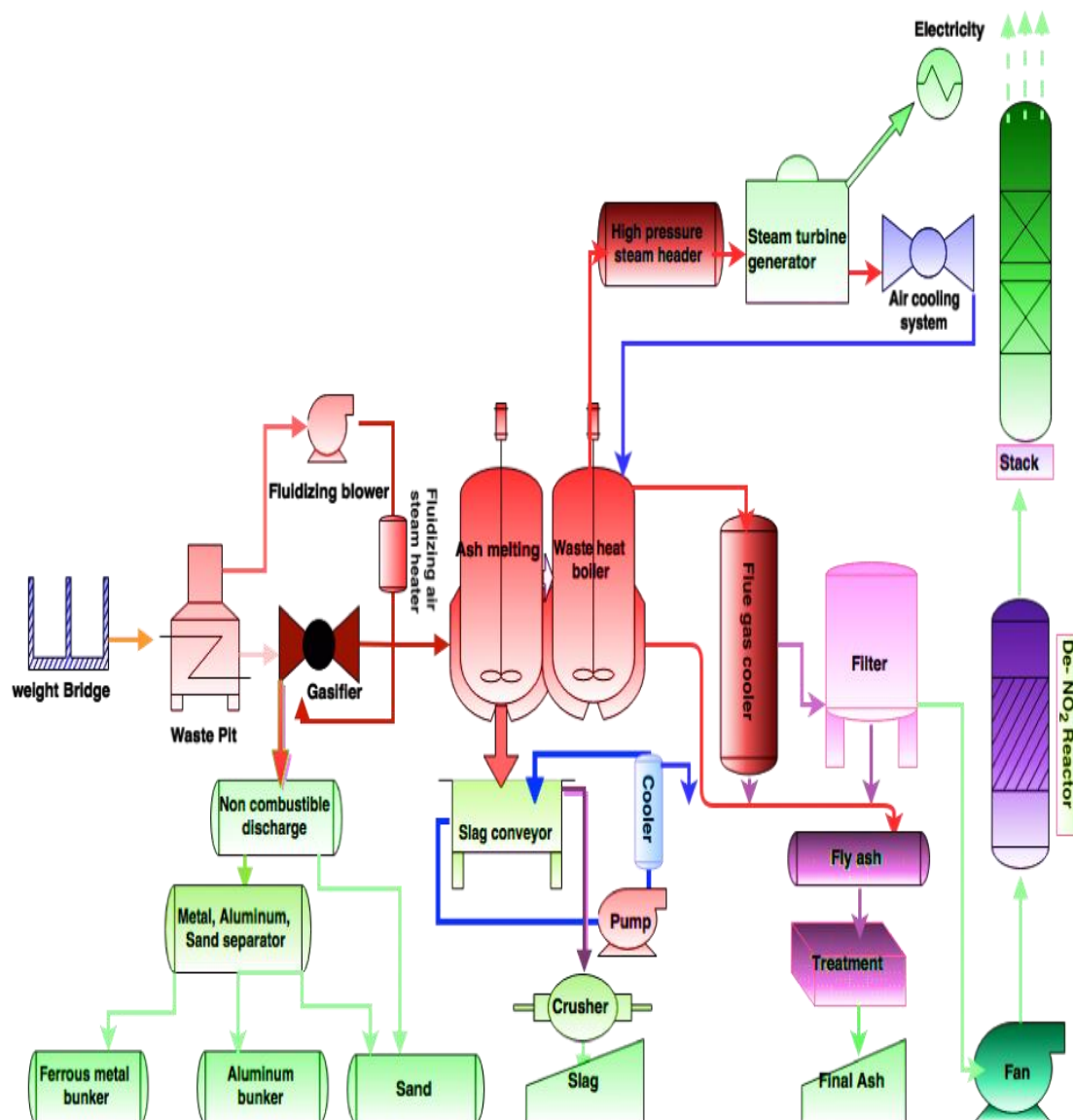
Figure 10. *Advance waste treatment plant*

The ash melting furnace and the waste heat boiler are directly connected to a heat boiler which has a high-pressure steam header that uses steam to generate power. The power generated is used to power the facilities and surplus sold. The steam is also used to provide hot water. The heat boiler discharges fly ash with flue gas at the bottom where the gas is taken back to the cooler while the ash is moved to a fly ash silo. This fly ash silo is also receiving ash from bag filter. Finally, fly ashes are treated by the treatment facility and sent to the hopper.

The gas is then cooled in water and filtered through filter bags made of fabrics to remove dust then reheated and passed through De-NO$_2$ reactor which removes nitrogen oxides contained in the gas as they react with ammonia through a catalytic reaction. Finally, it will discharge to the atmosphere by the stack. If we can implement this plant, our simulation result showed that GHG emission would be the same as of Kuraham waste management plant (Kurahama Sanitary Facilities Association, Japan). Thus, we can control environmental standard.

Proposed treatment plant's simulation result

Compared to the conventional waste treatment process, the High Tech system reduced the production of pollutants; particularly GHG is a million tonnes lower (180 to 0.03 thousand tonnes) as shown in *Figure 11* and *Table 2*.
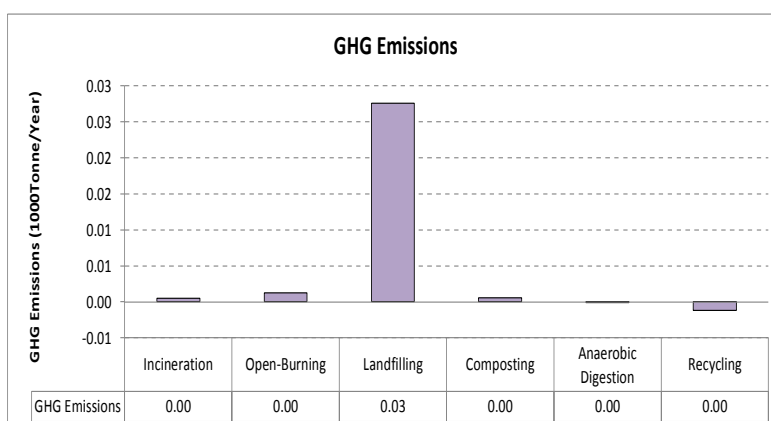

Figure 11. *Advance waste treatment plant gas emission*

Table 2. *Ranges of analytical data of the ground and surface water sample in Dhaka District, Bangladesh*

Parameter	Recommended values (WHO, 2004)	Water type											
		Ground water						Surface water					
		Pump water n = 113[a]			Deep tube well water n = 40[a]			River water n = 33[a]			MS water n = 120[a]		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
T (°C)	-	26.1	31.4	27.1	25.1	35.9	31	21.2	23.5	22.3	21.5	25.2	22.9
pH	6.5-8.5	7.1	8.3	7.87	7.6	8.1	7.88	7.1	7.9	7.43	7	8.6	7.46
EC (mS cm^{-1})	0.40	0.49	4.56	2.0	1.09	1.19	1.14	0.4	2.67	1.16	0.34	3.71	1.27
TDS (mg)	1000	271	1951	907.95	347	679	554.67	183	251	207.67	121	256	205.2
Ca2$^+$(mg)	100	37.7	299	112.13	42.1	71.3	54.57	8.3	86.1	40.1	6.3	224.7	39.63
Mg2$^+$(mg)	50	2.9	99.6	35.69	21.1	82.5	34.88	8.3	39.6	20.4	2.9	45.5	16.43
Na$^+$(mg)	200	201	946	549.89	241	417	339.67	215	709	382.33	139	539	304.9
K$^+$(mg)	12	4	55.9	17.79	5.2	8.2	6.95	2.9	18.9	8.67	6.1	45.7	15.96
HCO$_3^{2-}$(mg)	-	178	1360	427.21	209	330	271.5	180	345	270.67	118	479	199.15
Cl$^-$(mg)	250	163	718	350.79	130	291	196.83	117	163	145.33	63	359	225.8
NO$_2^-$(mg)	3	0.49	7.55	1.99	0.2	1.67	0.96	0.43	1.03	0.65	0.5	3.17	1.14
NO$_3^-$(mg)	50	1.3	47.9	17.74	0.8	12.9	6.57	6.3	17.9	10.23	0.4	73.9	15.42
SO$_4^{2-}$(mg)	250	110	1519	740.74	366	631	502.67	109	1239	531.67	117	988	342.5
As (μg)	10	13.3	108	39.97	36.1	66.1	44.4	3.01	38	15.00	4.03	50.1	10.03
Fe (mg)	0.3	0.1	4.01	0.78	0.14	2.1	0.60	0.09	0.39	0.2	0.02	0.29	0.13

Conclusion

The research concluded that the level of arsenic in different samples was higher than the acceptable level expected by WHO. The higher levels were mainly found in the ground water compared to the surface water were mainly due to waste dumping factors including the nature of waste, solubility that influence pH level, and concentration of different cations and anions. This High Tech waste treatment plant can potentially

reduce totally 2.4 million tons GHG per year. The plant can also produce 256.125 MW electricity daily. Thus, the system is self-sustainable and environmental friendly. It will reduce polluted wastewater effluents from flowing into the water bodies and GHG emission in the environment significantly. Further research is required to identify how electricity can be generated. Moreover, the study was conducted in a developing country. To enable generalization of the findings, the study suggests a similar research to be conducted concerning under-developed and developed nations.

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