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A COMPARATIVE STUDY ON THE EFFECTS OF TREATED AND UNTREATED TANNERY WASTES ON PLANT GROWTH

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Abstract

A net house pot experiment was conducted to compare the effect of untreated and treated wastes and effluents on soil properties and plant growth. It was observed that the untreated wastes and effluents from Hazaribagh tannery area contain comparatively higher amounts of N, S, P, Na, K and the heavy metals Cd, Cu, Pb and Zn compared to the ones collected from the Nayarhat tannery area where effluent treatment plant is in operation. The effluent and wastes from the latter industry were found cleaner and harmless to the environment. The pot experiment with plants grown on soil treated with different types and doses of wastes and effluents showed that although the plant growth might not be affected by untreated wastes and effluents as these provide huge nutritional elements but the plants accumulate greater amount of heavy metals which might be a threat to the consumer.

Key words: tannery waste, plant growth, heavy metals

Introduction

In Bangladesh, increasing industrialization threatens environmental quality and ecosystem, because most of the industries are discharging and dumping their wastes without treatments into the nearby water-bodies or in agricultural field. Pollution control issues are relatively recent in Bangladesh and very few industries are well equipped with pollution control systems. Department of Environment has identified 1200 polluting industrial units of which only 21 have taken environmental clearance from the DoE (DoE 1992).

Although the tannery industries are one of the most important and largest businesses in Bangladesh, except very few, most of them do not have any effluent treatment plant and discharge huge amount of untreated wastes and effluents. These waste materials are rich in Na, various organic substances and numerous heavy metals such as Cr, Cd, Pb, Cu, Zn, Mn etc. (Imamul Huq 1998). The tanneries in Hazaribagh are producing around 9,100 M^3 effluents per day. In addition to other chemicals, nearly 2000-

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3000 MT of sodium sulfide and nearly 3000 MT of basic chromium sulfate per year are being used for leather processing and tanning purpose (DoE 1992).

From the study of Naidu *et al.* (1999), it was found that long-term untreated tannery waste disposal severely contaminate soil and ground water. Imamul Huq (1998) also found from his study high levels of Cr including Zn, Mn, Cu and Pb to be present in the main waste disposal point, which exceeded toxic level range in the soils. Stamverg *et al.* (1994) noticed in his study that tannery waste could provide significant amounts of N and lime for crops, but uptake and accumulation of the heavy metals in plants from this contaminated soil and water have been known to result in negative impact on plant growth by affecting different plant processes, i.e., photosynthesis, carbohydrate metabolism, nitrogen metabolism, water relation and interference with the uptake and distribution of essential mineral nutrients in the plants (Joshi *et al.* 1999). The contaminants are known to cause delayed maturity and stunting of growth (Imamul Huq, 1998) and also decrease in yield (El-Kenawy *et al.* 1997). Application of tannery effluents to soil has been found to cause decreased rhizobial activity and suppression of nodulation in cowpea (Zohra and Imamul Huq 2003). The uptake of heavy metals by plants from contaminated soils is of great interest because an excess of dietary intake of some of these heavy metals might be deleterious to the health of the consumers (Page *et al.* 1981, Baath 1989, Roads *et al.* 1989, Gerzabek and Ullah 1990, Ullah *et al.* 1995).

However, if the industry discharges the effluents/wastes after treating them, these deleterious effects could be minimized. Very few tannery industries have effluent/waste treatment plants in the country. Of late, a few tanneries have these plants installed. In a recent study by the authors, it has been found that the tannery industries having effluent treatment plants create much lesser contamination of the surrounding water, soil and plant habitats than those where effluent treatment plants are not functional (Shabnam *et al.* 2008).

It is thus pertinent to have a comparative study on the effects of treated and non-treated waste materials on soil characteristics and plant growth. The outcome of such a study will be helpful to create awareness among the public as well as the policy makers about the importance of installing 'Effluent Treatment Plant' in the various polluting industries. With this view in mind, a macrocosm study was performed to check the heavy metal contamination in the growing plants receiving effluents from the two different types of sources.

Materials and Methods

A pot experiment was conducted in the net-house of the Department of Soil, Water and Environment, University of Dhaka. The solid wastes collected from the different tannery areas were processed for subsequent experiments and for physico-chemical analysis in the laboratory.

Sampling Site: Three sampling sites were selected for collecting the samples for the experiments.

i) Dhamrai in Dhaka district- unpolluted soil was collected from here to use in the pot experiment; the soils belong to the Dhamrai series. The soils were collected at 0 - 15 cm depth. No industrial establishments were located near the site.

ii) Hazaribagh Tannery Area- the largest and the worst polluted industrial area of Dhaka City situated on the bank of the Buriganga River; and

iii) Nayarhat tannery industrial area- with wastes treatment facilities, located at Dhamrai, on the bank of the Bongshi River.

Collection of Waste Samples: Solid wastes and effluents were collected from the source points of the two industrial areas- X tannery (representing the untreated effluent and waste) at Hazaribagh, and Y tannery (representing the treated effluent and waste) at Nayarhat. Solid wastes and effluents were taken in polythene bags and plastic containers respectively. The samples were preserved at normal temperature in laboratory.

Processing of Soil Samples: The collected soil samples were dried in air by spreading on separate sheet of papers after it was transported to the laboratory. After drying in air, the larger aggregates were broken gently by crushing it in a wooden mortar. A portion of the crushed soils was passed through a 2.0 mm sieve. The sieved soils were then preserved in plastic bags and labeled properly. These were later used for various chemical analyses. The rest of the soils were used for pot experiments.

Experimental Design: The pot experiment was conducted with a leafy-vegetable plant commonly known as Kalmi shak (*Ipomea aquatica)* in the net-house of the Department of Soil, Water and Environment, University of Dhaka. Three replications of each treatment were taken. The pots were arranged in a completely randomized way and 39 pots were used. The experiment was designed as follows: for the Hazaribagh site: plant type (1) × soil type (1) × solid waste type (2) × treatment (3) × replication (3) and for the Nayarhat site plant (1) × soil type (1) × effluent type (2) × treatment (3) × replication (3). Thus each experiment with polluted soils required 18 pots; and 3 pots contained the unpolluted soil used as absolute control.

Pot Preparation: Six kgs of air-dried soil samples were taken in each of the earthen pots. Wastes were mixed with the soil at a rate of 2.5 t ha^{-1}, 5.0 t ha^{-1} and 10.0 t ha^{-1}; and effluents were added with the soil at a rate of 100 ml kg^{-1}, 200 ml kg^{-1} and 300 ml kg^{-1}. For the control, no treatment was used.

Treatment Combinations: In order to study the effects of tannery wastes and effluents on plants, thirteen treatments were used. These are shown in Table 1.

Table 1. Treatment combinations with code numbers.

Treatment code	Treatment name
C	Unpolluted soil or control
HET1	Soil with untreated effluent– 100ml/kg (Hazaribagh)
HET2	Soil with untreated effluent–200ml/kg (Hazaribagh)
HET3	Soil with untreated effluent–300ml/kg (Hazaribagh)
BET1	Soil with treated effluent–100ml/kg (Nayarhat)
BET2	Soil with treated effluent–200ml/kg (Nayarhat)
BET3	Soil with treated effluent–300ml/kg (Nayarhat)
HWT1	Soil with untreated waste– 2.5 t/ha (Hazaribagh)
HWT2	Soil with untreated waste– 5.0 t/ha (Hazaribagh)
HWT3	Soil with untreated waste– 10.0 t/ha (Hazaribagh)
BWT1	Soil with treated waste– 2.5 t/ha (Nayarhat)
BWT2	Soil with treated waste– 5.0 t/ha (Nayarhat)
BWT3	Soil with treated waste– 10.0 t/ha (Nayarhat)

Experimental Plant: For the pot culture experiment, Kalmi shak (*Ipomea aquatica)* was grown on the soils spiked with the treated and untreated wastes and effluents to investigate its response to the changed quality of soil.

Sowing of Seeds: Fifteen seeds of the plant were sown in each of 39 pots. After one week of germination, three plants were uprooted and rests of the healthy seedlings were allowed to grow.

Watering: The pots were properly watered everyday. Sometimes they were watered at alternate day when the soil was saturated with rainwater. The moisture content of the soil was maintained between 50 and 80% field capacity throughout the growing period. Tap water was used for this purpose.

Collection and Processing of Plant Samples: The plants were harvested periodically after 15, 30 and 45 days of germination. Harvested plant samples were washed first with tap water and then with distilled water thrice to remove the soil particles and other extraneous materials. The root and shoot parts were separated with knife and processed separately. The samples were initially dried in the air and finally oven-dried to a constant weight at 70°C and ground. It was then mixed thoroughly to make it composite. The samples were kept in envelopes and labeled properly; stored in dry place for chemical analyses.

Laboratory Analyses of Physical and Physico-Chemical Properties of Soil and Waste: Moisture contents of air-dried samples were determined as describe by Black (1965). The particle size analyses of soils were conducted by hydrometer method as described by Black (1965) and the textural classes were determined by Marshall's Triangular Coordinates as devised by the United States Department of agriculture (USDA 1951). The pH of soils and wastes was measured electrochemically by using combined electrode digital pH meter as suggested by Jackson (1962). Soil pH was determined at a soil:water ratio of 1:2.5. As the wastes absorbed more water than soil, this ratio did not hold good. Therefore, the ratio was maintained at 1: 5 for waste to water. Electrical conductivity of the soils was measured at a soil: water ratio of 1:2 by an EC meter as described by USSL staff (1954). As the wastes absorbed more water than soil, this ratio was changed to 1: 5 for waste to water.

Organic carbon of samples was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1962). Organic matter was calculated by multiplying the percent value of organic carbon with the conventional Van-Bemmelen's factor of 1.724 (Piper 1950). Total nitrogen of the soils and wastes was determined by alkali distillation on the Kjeldahl's digest (Jackson 1962). Total phosphorus of samples was determined colorimetrically in the HNO_3:$HClO_4$ (2:1) digestion using a Shimadzu UV- VIS spectrophotometer at 420 nm wavelength after developing the yellow color with vanadomolybdate as described by Jackson (1962).

Total potassium and sodium contents were extracted by digesting the soils and wastes with HNO_3:$HClO_4$ (2:1). The extract was analyzed for total K and Na by a flame analyzer at 589 and 767 nm respectively (Jackson 1962). After digestion of the soils and wastes with HNO_3:$HClO_4$ (2:1), the extract was used to determine total sulfur content by turbidimetric method as described by Imamul Huq and Alam (2005) using a Shimadzu UV- VIS spectrophotometer at 420 nm .

The CEC of the soils and wastes were determined by extracting the soil with neutral ammonium acetate solution (NH_4OAc, pH- 7.0) followed by replacing the ammonium in the exchange complex by 2M KCl. The displaced ammonium was distilled in a way similar to the detection of available ammoniacal nitrogen (Black 1965). The exchangeable cations (Na^+, K^+, Ca^{++} and Mg^{++}) of soils and wastes were extracted with neutral normal ammonium acetate solution (NH_4OAc, pH- 7.0), as described by Piper (1950) and Jackson (1962). The extract was analyzed for total K and Na by a flame photometer analyzer at 589 and 767 nm respectively, and Ca and Mg was determined by EDTA (ethylene di-amine tetra acetic acid) method (Black 1965).

Total contents of Fe, Mn, Zn, Cu, Pb and Cd of the samples were determined by Atomic Absorption Spectrophotometer (Jackson 1962), after digestion with HNO_3: $HClO_4$ (2: 1) acid mixture.

Laboratory Analyses of Effluent and Water Sample: The pH of effluent and water samples was measured electrochemically by using combined electrode digital pH meter. Electrical conductivity of effluent and water samples was measured directly by an EC meter. Total dissolved solids include water soluble as well as insoluble matter. It was measured electrochemically by using TDS meter.

Organic carbon, total nitrogen, contents of PO_4-P and SO_4-S Na, K, Ca,Mg, total Fe, Mn, Zn, Pb, Cu and Cd were determined following the methods as described for soil or waste samples. The concentrations of Cl^-, $HCO3^-$ and $CO3^{2-}$ in water and effluent samples were determined titrimetrically (Imamul Huq and Alam 2005).

Laboratory Analyses of Plant Samples: Plant nitrogen was determined by alkali distillation of the Keldahl's digest (Jackson 1962). After wet oxidation with ternary acid mixture (HNO_3: H_2SO_4: $HClO_4$= 5: 1: 2) as described by Imam and Didar (2005), the total contents of P, S, Na, K, Fe, Mn, Zn, Pb, Cu and Cd were determined by using the procedures mentioned for soil.

Data Analysis: Microsoft Excel and MINITAB (version 13) were used for data manipulation, graphing and statistical analysis.

Results and Discussion

The pot experiment was carried out in a net house to observe and to compare the effects of untreated and treated solid wastes and effluents on plants (Kalmi shak) grown on a soil otherwise not contaminated. Soil belonging to the Dhamrai series was used as uncontaminated soil. Tap water was used for watering the pots. The properties of Dhamrai soil and the water quality are presented in the Tables 2 and 3. Some selected

Table 2. Some physical, physico-chemical and chemical properties of the Dhamrai soil.

Parameter		Dhamrai soil*
pH		7.10
EC (mS/cm)		10
Moisture (%)		11.30
Particle size analysis	Sand (%)	6.96
	Silt (%)	49.18
	Clay (%)	43.96
Texture		Silty clay
OC (%)		0.91
OM (%)		1.57
Total N (%)		0.28
Total P (%)		0.02
Total K (%)		0.251
Total S (%)		0.169
Total Na (%)		0.68
C/N ratio		3.25:1
CEC (meq/100g)		16.35
Exchangeable Na (meq/100g)		0.165
Exchangeable K (meq/100g)		0.133
Exchangeable Ca (meq/100g)		0.240
Exchangeable Mg (meq/100g)		0.117
Heavy metals (ppm)	Fe	21,533
	Mn	229.94
	Zn	38.12
	Cu	59.15
	Cd	0.00
	Pb	15.64

Table 3. Some chemical properties of the Irrigation water.

Parameter	Irrigation water
pH	6.4
EC (mS/cm)	14
TDS (g/L)	0.0
Available NH_4+NO_3 (ppm)	3.0
Available PO_4-P (ppm)	0.294
Available SO_4-S(ppm)	0.857
Available Na (ppm)	4.5
Available K (ppm)	0.5
Available Ca (ppm)	23.8
Available Mg (ppm)	4.5
Available Cl^-(ppm)	28
Available CO_3^{2-} (ppm)	n.d
Available HCl_3^- (ppm)	115
Fe(ppm)	n.d
Mn (ppm)	0.044
Zn (ppm)	n.d
Cu (ppm)	n.d
Cd (ppm)	n.d
Pb (ppm)	n.d

n.d. = not detected

Table 4. The average value of some physico-chemical properties of wastes collected *in situ* at Hazaribagh and Nayarhat tannery industrial area.

properties		Hazaribagh tannery industrial area	Nayarhat tannery industrial area
pH		9.03	5.85
Ec (mS/cm)		490	425
CEC (meq/100g)		33.240	47.520
Exchangeable cation (meq/100g)	Na	6.511	1.406
	K	0.390	0.293
	Ca	4.048	1.118
	Mg	2.014	0.177
OC (%)		4.503	12.700
OM (%)		7.910	21.830
Total N (%)		0.993	0.22
Total P (%)		0.495	0.150
Total K (%)		2.033	0.710
Total S (%)		1.373	0.479
C/N ratio		4.717	57.705

Table 5. The average value of some selected chemical characteristics of effluents collected *in situ* at Hazaribagh and Nayarhat industrial area.

properties	Hazaribagh tannery industrial area	Nayarhat tannery industrial area
pH	6.6	7.05
Ec (mS/cm)	3674	235
TDS (g/L)	17.07	9.8
OC (%)	0.06	0.003
Available NH_4+NO_3 (ppm)	873.89	2.22
Av-Na (ppm)	1522	376

Table 6. The average value of some heavy metal concentration of wastes and effluents collected *in situ* at Hazaribagh and Nayarhat tannery industrial area.

Heavy metals	Hazaribagh tannery industrial area		Nayarhat tannery industrial area	
	Wastes	Effluents	Wastes	Effluents
Fe (ppm)	19073	2.567	2957	0.132
Mn (ppm)	351.57	1.829	19.00	0.097
Cu (ppm)	797.97	2.719	38.69	0.017
Cd (ppm)	7.54	0.025	0.001	0.0
Pb (ppm)	181.40	1.05	68.85	0.0
Zn (ppm)	99.70	1.829	16.38	0.002

properties and heavy metal content of the wastes and effluents that have been used for spiking the soil are put in the Tables 4, 5 and 6. In this experiment, the growth has been estimated on dry weight basis for five plants. The average growth in relation to the treatment is shown in the Table 7.

Average dry matter production was found to be affected by type and amount of waste materials. The yield of both roots and shoots grown on soils spiked with different wastes were found significantly affected by the materials at 0.1% level ($F=9.64$ for treatment and $F=168.17$ at $p=$below 0.001 for growth in case of roots; $F=7.17$ for treatment and $F=200.64$ at $p=$below 0.001 for growth in case of shoots).

From the mean values of yield (Table 7), it appeared that the plant growth (dry matter weights of both root and shoot) was better with either treated effluent (BET3) or treated waste (BWT3). Dry matter production has been found to be adversely affected by untreated effluent or wastes compared to the control. This gives a clear indication that the untreated effluent or wastes from tannery industries contain materials that are liable to affect crop production, particularly Kalmi, as is evident from the present observation.

Table 7. Average yield of Kalmi (dry weight basis, g/5 plants).

Treatment	Plant root			Plant shoot		
	15 day	30 day	45 day	15 day	30 day	45 day
C	0.55	0.89	1.22	1.56	2.02	2.95
HET1	0.43	0.77	1.39	1.33	2.55	2.84
HET2	0.29	0.52	0.94	1.89	2.69	2.97
HET3	0.38	0.67	0.88	1.76	2.38	3.01
BET1	0.37	0.64	0.98	1.54	2.12	2.45
BET2	0.56	0.88	1.04	2.04	2.88	3.38
BET3	0.64	1.05	1.45	2.00	2.91	3.57
HWT1	0.51	0.97	1.28	2.12	2.78	3.09
HWT2	0.55	0.74	1.33	1.47	2.45	3.18
HWT3	0.28	0.56	0.96	1.66	2.79	3.42
BWT1	0.44	0.67	0.98	1.87	2.61	3.22
BWT2	0.61	0.88	1.13	1.99	2.88	3.51
BWT3	0.63	1.23	1.55	2.34	2.88	3.28

LSD at 0.1% level is 0.521

From t-tests no significant variation were found in root and shoot growth in relation to two types of waste materials. The t value for root is 0.7 at p=0.49 and t value for shoot is 0.82 at p=0.47.

To compare the accumulated concentration of elements in the plant, t-test was done (Tables 8 and 9). In case of nitrogen accumulation, significant difference was found in root (t=2.31, p=0.027). In shoot, nitrogen content did not differ significantly (t=0.62, p=0.539). Phosphorus and potassium content in both roots and shoots were also found insignificant in t-test. The t-values for P in root and shoot are 0.12 at p=0.907 and 0.91 at p=0.369 respectively. The t-values for K in root and shoot are 0.45 at p=0.658 and 0.69 at p=0.493 respectively. Sodium concentration in root was found insignificant but in shoot it showed significant difference (t=3.72, p=0.003). For S the situation has been opposite. Sulfur content in root was found significant (t=2.54, p=0.016) but in shoot it was insignificant (t=0.58, p=0.565).

Among the heavy metals Fe, Mn, Cu, Cd, Pb and Zn were analyzed. The phyto-availability of Cr is very little and risk to human and animal health is minimal (USEPA 1993, Naidu and Kookana 1999, Banu *et al.* 1999); for this reason Cr was not analyzed.

When the effect of individual treatment is considered, it can be observed from the Figures 1, 2, 3 and 4 that the heavy metal concentrations increased with increasing treatment doses. It was found that Zn accumulated in higher amount in shoot than root. For this metal, the solid waste effect was found to be greater than the treatment with the effluent (Figure 1).

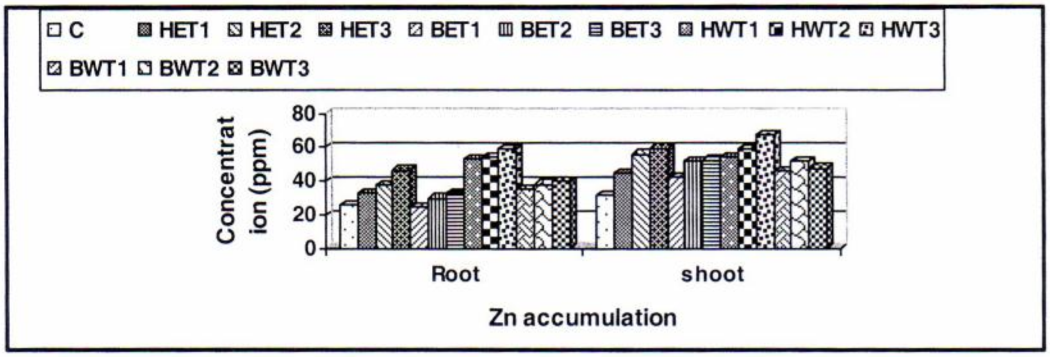

Figure 1. Effect of untreated and treated tannery wastes and effluents on Zinc accumulation in plant parts.

Plant was found to accumulate higher amount of Cu in root than in shoot when treated with waste. But in shoots higher concentration was found when treated with effluents (Figure 2). Copper concentration was found higher in plants receiving non-treated waste or effluent while the heavy metal concentrations were lower in plant parts grown on soil receiving treated wastes and effluents.

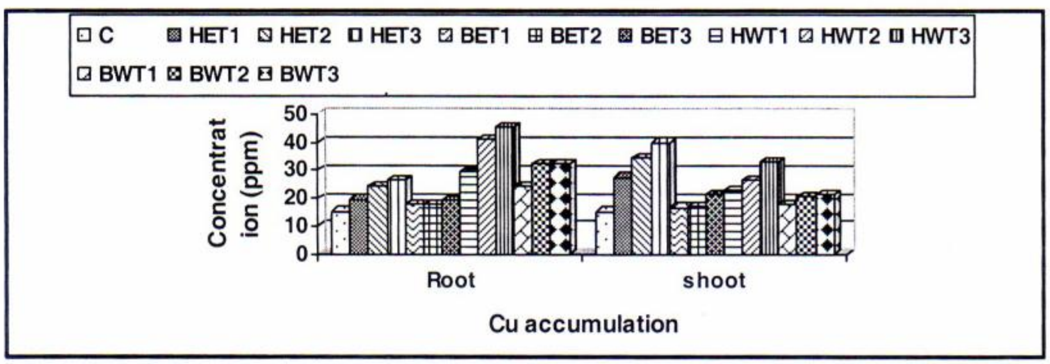

Figure 2. Effect of untreated and treated tannery wastes and effluents on Copper accumulation in plant parts.

Cadmium accumulation was not found in plants treated with treated effluents (Figure 3). Untreated solid wastes caused more Cd uptake than the untreated effluent. For lead uptake also, the effect of untreated solid waste was greater than the untreated effluent (Figure 4).

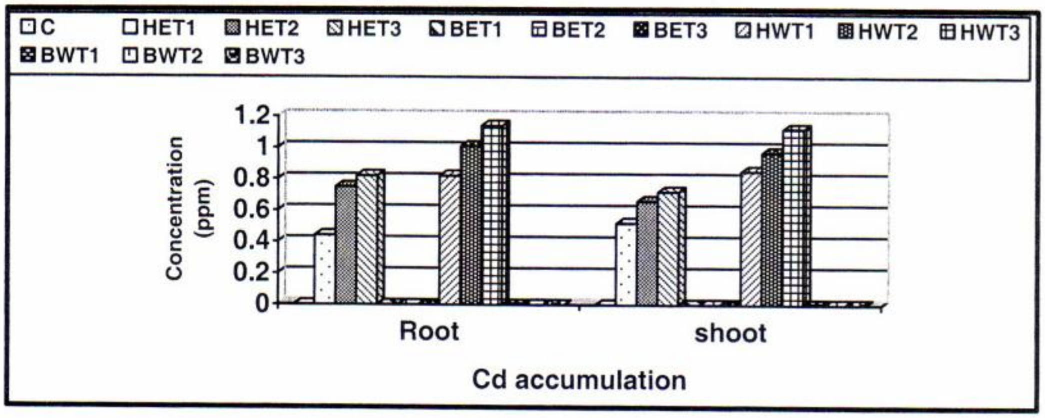

Figure 3. Effect of untreated and treated tannery wastes and effluents on Cadmium accumulation in plant parts.

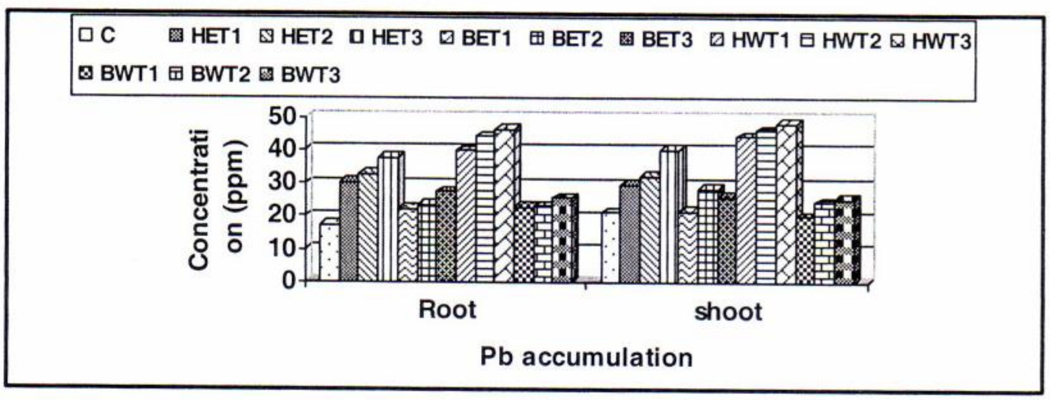

Figure 4. Effect of untreated and treated tannery wastes and effluents on lead accumulation in plant parts.

The heavy metal accumulation differed positively both in roots and shoots due to treatments. Zinc concentration in root was found to differ significantly but in shoot it differed positively but not significantly (for root t=3.72 at p=0.003 and for shoot t=1.62 at p=0.12). For Cu the situation was found opposite. Copper content in root was found insignificant (t=1.63, p=0.113) but in shoot it was highly significant (t=2.82, p=0.008). Lead and Cd accumulation was found to be highly significant both in roots and shoots. In case of root the t values were 10.89 and 5.04 for Cd and Pb respectively and in shoot the t values were 6.93 and 4.53 for Cd and Pd respectively; in all the cases the p values were below 0.01.

The pot experiment with plants grown on soil treated with different types and doses of wastes and effluents showed that although the plant growth might not be significantly affected by untreated wastes and effluents as these provide huge nutritional elements but the plants accumulate greater amounts of heavy metals which might become a threat to the consumer. The treated wastes and effluents have been found to exert less toxic effect on the accumulation of heavy metals in the food chain.

Conclusion

As a poor country, Bangladesh desperately needs industrialization for its development. The tannery industries are very important as Bangladesh earns much more foreign currency from this sector but growth of these industries have caused a serious environmental problem because of the wastes and effluents that these industries are producing. These Industries have traditionally adhered to a minimum-cost production philosophy, overlooking social/environmental responsibilities. It naturally questions investment in effluent treatment which is considered as a non-productive activity but causing serious environmental pollution. Whereas, if these industries would have effluent treatment facilities, this could minimize the risk.

Protecting the environment from industrial pollution however is not merely a problem of waste treatment. It is essentially a management problem. Waste is a misplaced resource and the challenge in wastes and effluents management is to identify a scheme of modifying inputs, modifying production processes and recovering by-products to make profits for industry while satisfying effluent standards.

The city of Dhaka today is at the threshold of industrialization. More units for new products are being set up continuously. The errors of past should not be repeated; rather the lessons and knowledge from abroad should be utilized to create conditions suitable for man and infrastructures fit for environment. In this respect, considering the Bangladesh situation, installing ETPs in polluting industries, is strongly recommended.

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