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DISSEMINATING TEXTILE SLUDGE INDUCED HEAVY METAL CONTAMINATION AND ASSOCIATED HEALTH RISKS IN CONTEXT OF DHAKA, BANGLADESH

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ABSTRACT

This study investigates the present scenario of heavy metal contamination in textile sludge along with their associated health problems, their removal efficiencies, alternative usage, and challenges to handling them in the perspective of Bangladesh. Textile sludge is considered to be the biggest source of hazardous elements and has the potential characteristics to create different diseases in human beings including cancer. Since the sludge is associated with a high load of heavy metals, it poses threat to both environment and human health if they remain untreated in an open environment. The methodology of this study focuses on a systematic review of data related to sludge-induced heavy metal contamination around Dhaka city. Results showed that Cr, Ni, Cu, As, Pb, and Cd were found to be dominant elements in the sludge that may pose serious threats to human health. This study also pointed out some treatment methods to remove heavy metals from textile sludge load, but however, still, there is a long way to implement them on a large scale with reduced economic, health, and environmental costs. This study concludes that further analysis is needed to remove heavy metals and encourages the emerging application of textile sludge for sustainable development in the health economic sector of the country.

INTRODUCTION

Sludge is considered to be one of the most objectionable industrial discharged compounds that create environmental degradation and pose human health threat (Adyel et al., 2012a; Adyel et al., 2012b; Adyel, 2012c). Exports of textiles, clothing and ready-made garments (RMG) are the major export sectors of Bangladesh contributing to 80% of total national earning and 15% of total GDP (Adnan et al., 2015). Textile manufacturing processes involved different steps like dyeing, printing, finishing, bleaching, washing, dry cleaning, weaving, sizing, spinning etc. All of these steps involves usage of huge amount of dyes, solvents, optical brighteners, crease-resistance agents, flame retardants, heavy metals, pesticides and antimicrobial agents (Islam et al., 2009).

Currently there are more than 4000 production units in this sector of which only 52% possess water treatment plant (WTP) (Adyel et al., 2012b; Adyel, 2012c). Studies found that around 2.82 million m^3 of waste water is generated every day in Bangladesh which is correspondent to generation of 1.14 kg solid sludge/m^3 of waste water. In 2012 alone, the production of textile WTP sludge was 36 Mt and most of these portions were discarded to the environment without further treatment (Golder et al., 2006).

Sludge typically contain heavy metals, organic compounds, macro and micro nutrients, organic micro pollutants, microrganisms and eggs of parasitic organisms (Chen et al., 2015). This complex constituents of sludge create environmental

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degradation and bioavailable nature of these waste may lead to the secondary environmental pollution (Figure 1) (Islam et al., 2017).

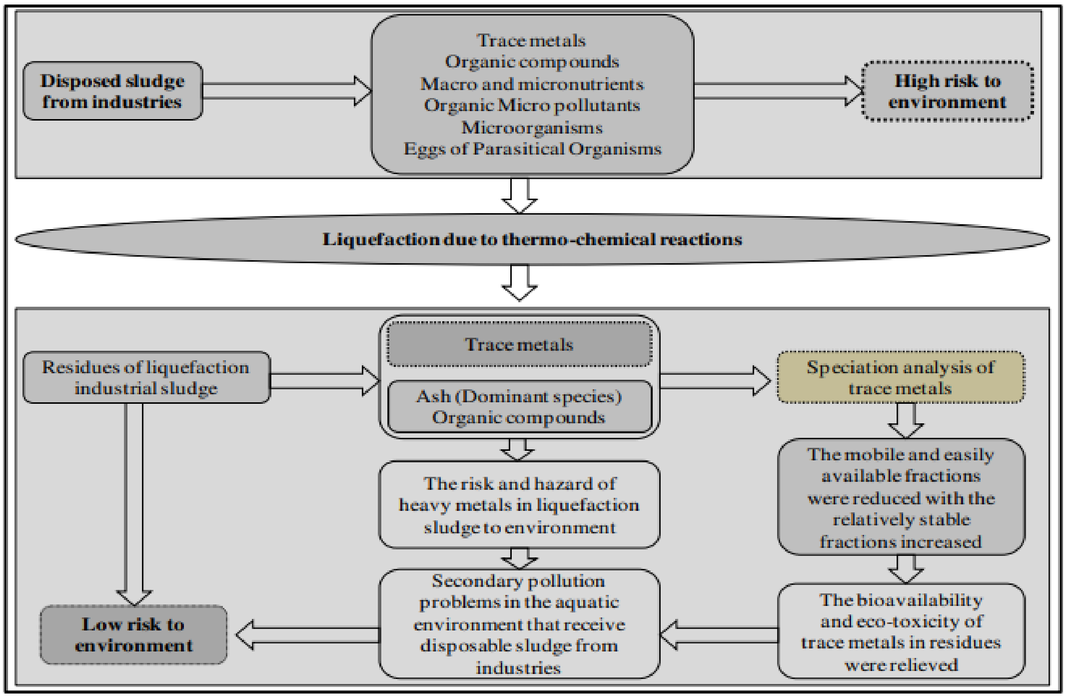

Figure 1. Transformation Scenario of Heavy Metals in Environment (Islam et al., 2017)

Most commonly found heavy metals in sludge are Cd, Z, Cu, Cr, Co, Pb, Mn, Ni, Hg etc. (Islam et al., 2009). These metals are considered to be hazardous because of their non-biodegradable characteristics, long biological half lives and their tendency to accumulate in human and animal tissues that is called bioaccumulation and bio magnification which subsequently lead to various diseases and disorders (Manahan, 2005). This sludge discarded heavy metals could leach to ground water, accumulate in soil and could be subsequently up taken by plants and crops (Alom, 2016).

Dhaka is one of the most densely populated cities (12 million people living in 815.8 km^2 area) in the world with significant number of textile industries (Bhuiyan et al., 2011). Currently the older and newly established textile industries at the vicinity of Dhaka city pose a serious threat to human health and environment [18]. As a direct consequence, sludge from different textile industries found their ways to different arable and non-arable lands that may result the contamination of heavy metals in nearby surface water and soil (Ahmad et al., 2010).

In developed countries, sludge is handled by reducing their weight and volumes. In Bangladesh, sludge is treated by some traditional ways like incineration, composting and landfilling (DoE, 2015). However, these systems are costly and required more man power. For example, proper incineration system for sludge management requires trained staffs to prevent potential fire, flue gas emission and leachates of ashes that pose potential risks. In addition, sludge contaminated with heavy metals and other hazardous elements make their characteristics less desirable to make landfilling or composting (Patel & Pandey, 2009). So the objective of this review study was set to lighten up the current scenario of textile sludge induced heavy metal contamination in perspective of Bangladesh. This study also emphasizes that sustainable usage of textile sludge could be emerging options to manage the ever increasing sludge volume.

SPECIATION OF HEAVY METALS IN TEXTILE SLUDGE

The sequential methods of extraction or textile sludge characterizes a detailed information on the potential mobility and association of heavy metals with different phases of sludge (Chen et al., 2015). The presence of trace amount of heavy metals in textile sludge may lead to detrimental effects on ecosystem due to their accumulative behavior and hazardous effects. The hazardous characteristics of heavy metal is dependent on their speciation in sludge (Table 1) (Chen et al., 2008).

Table 1. Fraction relation of trace metals with toxicity and bioavailability (Chen et al., 2008)

Metallic fraction	Toxicity	Bioavailability
Exchangeable fraction /soluble to acid (F1)	Directly toxic	Fraction effects directly
Reducible fraction (F2)	Potentially toxic	Fraction effects potentially
Oxidizable fraction (F3)		
Residual fraction (F4)	Relatively non-toxic	Stable fraction

The exchangeable fraction (F1) characterized with high bioavailability of associated metals. The reducible fraction (F2) indicates that heavy metals on the sludge are thermodynamically unstable and could also remain available under anoxia condition (Fuentes et al., 2008). Thus, these two factors pose direct effects on environment. The oxidizable fraction (F3) can easily get mobilized and transformed to F1 or F2. Studies revealed that metallic solubility become increased when they get contacted with organic matter in oxidized conditions (Yao et al., 2010). The residual fraction (F4) is considered to be bound within the crystal structure and thus identified as a stable fraction (Fuentes et al., 2008).

Islam et al. (2017) found metal association in the sludge in accordance with the following trends-
Ni=residual>oxidizable>reducible>exchangeable;Cr=residual>exchangeable>reducible>oxidizable;Cu=residual>oxidizable>reducible>exchangeable;Cd=residual>oxidizable>exchangeable>reducible;As=residual>oxidizable>reducible>exchangeable And Pb= residual>oxidizable>exchangeable>reducible.

These results indicated that all of these heavy metals possess the tendency to leach out in the environment (Chen et al. 2008).

PRESENCE OF HEAVY METALS IN TEXTILE SLUDGE

Table 2 represents the association of heavy metals in sludge from different areas around the Dhaka city. Results indicates that almost all the trace elements crossed the permissible limits according to USEPA 1999. These findings assumed that sludge deviated heavy metals can cause metallic pollution to the surrounding environment.

Table 2. Representation of Sludge Associated Heavy Metals Contamination (mg/kg) Scenario around Dhaka City

Heavy Metals	Heavy Metal Concentration according to Islam et al. 2017	Heavy Metal Concentration according to Anwar et al. 2018	Heavy Metal Concentration according to Nessa et al. 2016	Heavy Metal Concentration according to Islam, 2009	Permissible limit according to USEPA, 1999
Cr	30.5	10	17.7	4.35	26
Ni	15.3	32	10.3	-	16
Cu	14.3	58	164.1	1347.7	16
As	20	-	-	-	6
Cd	4.2	5.6	0.3	6.27	0.6
Pb	6.2	12	9.7	79.13	31

IMPACTS OF HEAVY METALS ON HUMAN HEALTH

Elements with specific gravity more than 5 with 63.5-200.6 atomic mass are considered to be heavy metals (Fu & Wang, 2011). Examples of sludge associated heavy metals are Cr, Ni, Cu, As, Cd, Pb, Co, Zn etc. They are hazardous to all living organisms since they have stable tendency to occur bioaccumulation and bio magnification (Kragovic´ et al., 2013).

Contamination of Cr creates allergic dermatitis to humans and disrupt the food chain of ecosystem by inhibiting the natural photosynthesis process even at lower concentration (Sherene, 2010). As has strong adsorption characteristics with sediment. People exposed to as contamination mainly through ground water source. It can cause sleep disorder, abnormality, learning impairment in children, neurological damage to the adult and can lead to cancer for chronic exposure (Yadav et al., 2011). Another hazardous heavy metal is Pb which can bioaccumulate in an organ's body that may lead to poisoning or even death. Children affected by Pb may suffer from lower IQ, hyperactivity, mental retardation etc. Contamination of Cd is also become poisonous due to its high bio-persistent nature with toxicological properties (Järup, 2003).

REMOVAL TECHNIQUES OF HEAVY METAL FROM TEXTILE SLUDGE

One of the popular techniques to remove heavy metals from textile sludge is washing technique. This technique could be applied in both in-situ and ex-situ facilities (Wood, 1997). Since most of the metal ions are insoluble in water, addition of flushing chemicals in certain ratio are required to extract them. Some commonly used flushing agents are distilled water, acid, base, surfactants, chelates, solvents etc. (Gebreyesus, 2015). Metallic flushing through these techniques are most cost effective and less damaging (Gebreyesus, 2015). Name of some popular flushing agents are EDTA (Ethylenediaminetetraacetic acid), NTA (Nitrilotriacetic acid), DTPA (Diethylenetriaminepentaacetic acid), CA (Citric acid) etc. form relatively stable materials with most heavy metals over a wide range of pH (Bilgin & Tulun, 2016).

Sumalatha et al. (2019a) have studied the soil washing technique on heavy metal contaminated textile sludge with 0.1N HCl, 0.1N EDTA and 0.1N $FeCl_3$. The removal efficiencies for 0.1N HCl were Cd (64.5%)>Cu (57.9%)>Zn (52.3%)>Ni (45.3%)>Pb (28.5%)>Fe (22.6%). Soil washing with 0.1N EDTA showed the following heavy metal removal efficiencies- Cd (82.9%)>Cu (82.5%)>Zn (79.5%)>Ni (59.3%)>Pb (55.5%)>Fe (49.3%)>Cr (42.7%). Finally, by applying technique with 0.1 N $FeCl_3$, heavy metal removal from textile sludge showed the following descending order- Cd (98.8%)>Pb (98.7%)>Zn (97.2%)>Cu (95.8%)>Fe (82.8%)>Ni (79.9%)>Cr (72.1%). Similar kind of study was also done by Gitipour et al. 2016 with HCl and EDTA and found heavy metal removal efficiencies in between 66.8%-82.69%.

Sumalatha et al. (2019b) further proposed heavy metal removal technique from textile sludge materials with combination of several flushing agents. This time they used distilled water and 0.1N HCl+0.1N EDTA complex to examine the heavy metal reduction efficiencies. Result for heavy metal removal by distilled water showed less efficiency for Zn, Cu and Ni removal. For 0.1N HCl+0.1N EDTA flushing agents, the heavy metal removal efficiency was found to be 71-98%.

Besides these chemical applications, biological techniques also become promising in removal of heavy metals from textile sludge. For examples, Yuvaraj et al. (2018) used epigeic earthworms named *Eudrilus eugeniae* and *Perionyx* *excavates* that showed the removal efficiency performance of Cd by 54.5%, Cu by 36.0% Cr by 37.0% and Zn by 35.9%. Some recent eco-toxicological reports revealed that earthworms accelerate the sludge mineralization processes and consume heavy metals (Usmani et al., 2017; Wang et al., 2018). Two types of mechanisms could be worked here- (i) heavy metals are bioaccumulated in the inside of the earthworms' body (Yuvaraj et al., 2018) and (ii) transformed to soluble fraction of heavy metals during the vermistabilization process (Wang et al., 2013). Coelho et al. (2018) found that significant amount of Cd, Cu, Zn, Ni, Pb can be adsorbed by earthworm *E. fetida*.

ALTERNATIVE USAGE OF SLUDGE

Textile sludge can be used in various productive ways. For examples about 1000 tons of textile sludge has been using by Indian cement company name Aditya Birla per month (Battacharjee & Bharadwaj, 2015). Iqbal et al. (2014) found that applying incineration technique to manage textile sludge is an acceptable disposal method for Bangladeshi context. Some other studies found that systematic mixing of textile sludge with cow dung can produce biogas for household usage (Guha et al., 2016). Applying textile sludge in agricultural uses like as compost materials or as landfilling materials, Bangladesh is likely to follow the European Standard guidelines. However, global land use application of textile sludge is become contradictory due to its leaching behavior of heavy metals and other hazardous chemicals (Teoh & Li, 2020).

Besides these, several studies found that sludge can be used as brick materials in context of Australia and UK (Klein, 2019). Zhan and Poon (2015) suggested that textile materials are used in manufacturing of non-load bearing concrete blocks in China. Several studies in terms of Bangladesh suggested that textile sludge has the potentiality to make bricks (Anwar et al., 2018). Hossain et al. (2018) applied gamma radiation to detoxify stable dye materials in textile sludge and mix 50% of them with clay to make solid bricks. Since brick manufacturing sector is one of the emerging sectors for country's development, more research should be done to facilitate the sludge materials to conserve the top soil. In addition, textile sludge co-processed with cement materials have also the potentiality to use in roadways, sanitary latrine rings as well as in septic tanks (Guha et al., 2016).

CHALLENGES TO MANAGE TEXTILE SLUDGE

The National Standard Guidelines was developed for Bangladesh in 5 years long deliberate process with the support of DoE and GIZ. Several pilot demonstrations like incineration, anaerobic digestion and co-processing in cement kilns were done to evaluate their feasibility rate for sludge management. The test results of these pilot projects suggested that composting, agricultural use and recycling in brick or cement industries could be meaningful options to manage the textile sludge (DoE, 2015). No clear estimation is existed regarding the total amount of sludge production in all textile industries of the country. One previous study calculated that 36,000 metric tons of sludge was generated from textile ETPs alone in 2012 (Anwar et al., 2018) and this amount turned to increase 49,442 metric tons in 2016 and expected to cross the 80,000 metric tons load in 2021 (Hossain et al., 2018). However, it is not evident that whether these options could serve the ever growing amount of textile sludge in terms of Bangladesh.

CONCLUSION

A significant amount of textile sludge is producing in Bangladesh with increasing trends in each year. Along with other hazardous chemicals, heavy metals are also leached out from the sludge and pose both environmental and human health threat. Though there are some treatment options for sludge management, high efficiency percentage especially for heavy metal removal is still in long run. Besides that, there are also some major challenges that has to be resolved in context of country's economic viability. Further research is recommended to explore more efficient method to reduce heavy metal loads from the ever growing textile sludge.

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