Saudi Journal of Biological Sciences 25 (2018) 1326–1331

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

Pollutant fate and spatio-temporal variation and degree of sedimentation of industrial- and municipal wastes in Chakbandi drain and River Chenab

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ARTICLE INFO

Article history:
Received 22 June 2018
Revised 10 August 2018
Accepted 14 August 2018
Available online 21 August 2018

Keywords:
Human impact
Industrialization
Heavy metals
Freshwater
Pollution

ABSTRACT

This study's objective was to assess a seasonal impact of industrial and sewage waste disposal on water quality of the river upstream Trimu Head. Considering the significance of the river, drain wastewater was analyzed during the summer and the winter seasons from pre-determined locations. Water quality parameters were recorded higher than the maximum permissible limits prescribed by WHO for freshwater bodies. Level of these Physio-chemical variables was higher in the winter due to the least amount of water from domestic sewage. Although some of these parameters indicated sedimentation hitherto the water quality of River Chenab was found very poor due to the pollution bestowed by tributary waste water from drains. Findings of this investigation suggest the importance of continuous monitoring and assessment to improve the water quality of the river. This study provides a baseline data which may be compared to assess any further deterioration in the water quality and may also be used to plan future monitoring and required restoration of habitat for the safe supply of fish to the population of this region.

1. Introduction

The rapid urbanization and industrialization have caused an increased deterioration in the quality of surface and groundwater (Su et al., 2011). Unfortunately, poor monitoring of water resources management in the country has severely impacted the water quality of the freshwater ecosystem. The increase in population, land development, and industrialization has resulted in the production of a huge amount of organic and inorganic wastes, polluting freshwater bodies (Kamble, 2014; Mohamed et al., 2013: Sumok, 2001). The evaluation of water quality in developing countries has become one of the most serious issues in recent years. The majority of rivers in Asia serve as a sink of effluents discharged from industries (Phiri et al., 2005; Suthar et al., 2010). The present method of dropping these waste effluents and their ultimate disposal to river systems is derisory and unplanned. In Pakistan, the planning and development of tributary drain conveying effluents to the rivers are in the hands of municipal bodies and corporations suffering from negligence and lack of funds (Nasrullah et al., 2006). The net result is acute pollution of these freshwater bodies acting as a prime source of water supply for agricultural activities. Such type of water quality degradation is responsible for the death of aquatic lives, crop failure and human health hazards (Kamble, 2014) and loss of aesthetics (Nasrullah et al., 2006). Sediment erosion and their accumulation pattern may cause spatio-temporal changes of sediment quantity in freshwater reservoirs (Alexeevsky et al., 2013). The suspended-phase transportation of various organic and inorganic pollutants due to various anthropogenic activities at some locations dominates the total transport (Chalov et al., 2012, 2015). Such impacts can be observed in the suspended particulate matter (SPM), particulate organic matter (POM), and sediment-associated chemical constituents (Chalov et al., 2015; Jung et al., 2016).

There is a lack of concern from industrialist and environmental protection agencies towards the treatment of toxic wastes prior to discharge into sewer or open surface drains, etc. This untreated wastewater not only pollutes freshwater bodies but also produces bad odor and tainted smell (Kulkarni, 1997). Untreated industrial effluents are a major source of freshwater pollution and further making the underground water unsuitable for drinking in Pakistan

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2018.08.015
1319-562X/

(Hari et al., 1994). It is alarming that most of the industries in Faisalabad like other industries in the country are without wastewater treatment plants. Only a few of them have this facility, they do not use and release toxic dyes and metals valiantly (Hussain, 2014). Such anthropogenic heavy metals accumulate in animal tissues, including human through food chains. Heavy metal pollution is threatening the world's freshwater resources (Mohamed et al., 2013; Vörösmarty et al., 2010).

This study evaluates a broader understanding of the sources, freshwater pollution, and heavy metal contamination in the current scenario. The objective of this work was to evaluate and analyze the spatial and temporal variations in water quality due to toxic industrial and municipal waste production, (ii) its sedimentation in tributary drains and an ultimate effect on the River Chenab water quality upstream Trimu Head.

2. Materials and methods

2.1. Study area

The River Chenab receives industrial and domestic sewage wastes through the Chakbandi main (CBM) drain. This wastewater holds genotoxic and cytotoxic potential in the form of toxic chemicals from a variety of industries in Faisalabad. A study area (Fig. 1) was selected on the basis of earlier reports by Hussain et al. (2016). Five sites (Sites D1 to D5) along the stretch of the drain and three sites along the river (Sites R1, R2 and R3) downstream (31.570° & 72.534°) to the entrance of the CBM drain into the river upstream Trimu Head were selected (Fig. 2). Two sampling sites U1 and U2 along the river before the entrance of drain into the river were selected as controls.

2.2. Water analyses

Wastewater samples were collected from pre-determined locations of the River Chenab's CBM drain in the early and late hours (06–07 am, 07–09 pm) of the day. Some of the parameters (water temperature, pH, electrical conductivity) were analyzed on the spot by following the methodology as described by Boyd (1981). The water samples were collected in 3 L polyethylene bottles with the help of a water sampler. Water samples were shifted to the Fisheries Research Laboratories and analyzed within 4–8 h, according to the standard methods as described in APHA (1985). The water samples for heavy metal analysis were preserved by adding 5 ml of 55% HNO_3 (Merck, Darmstadt, Germany) to prevent metal adsorption on the inner surface of the container and stored at 4 °C before analysis (Boyd, 1981). Metals analyzed were cadmium (Cd), copper (Cu), manganese (Mn), zinc (Zn), lead (Pb), chromium (Cr), tin (Sn), and mercury (Hg). The concentration of each metal was determined using metal kits (Spectroquant® Analysis System, Merck) and using nitrous oxide/acetylene flame atomic absorption spectrophotometer (2000 series, High-Technologies Corporation, Chiyoda, Tokyo, Japan) with Zeeman background correction.

3. Results

The concentration of total dissolved solids (TDS) and salinity showed considerable dilution at sampling site R1. Total suspended solids (TSS) did not show any type of dilution at site R1. TDS and TSS showed decreasing trend from D1 to D5 indicating sedimentation in the drain. On-site D5 all parameters (TDS, TSS, and salinity) showed comparatively higher concentrations and sudden decrease of samples collected from site R1 due to the dilution of the wastewater by the river water in summer. TDS and salinity in the River water reduced almost to its one third in water samples collected from location R1. In the winter season, all parameters showed higher concentrations and decreasing trend from D2 to R3 except D5. There is a non-significant dilution of the drain, wastewater on-site R1 in the winter. This is due to the fact that in the winter there is very a low water level/almost no in the river. It is ~~an~~ important to point out that TSS showed a similar pattern and slightly higher concentrations in the winter and showed no dilution in summer as other variables. The level of TDS, TSS, and salinity at control sites (U1 and U2) upstream of CBM drain were recorded within permissible limits (Fig. 3).

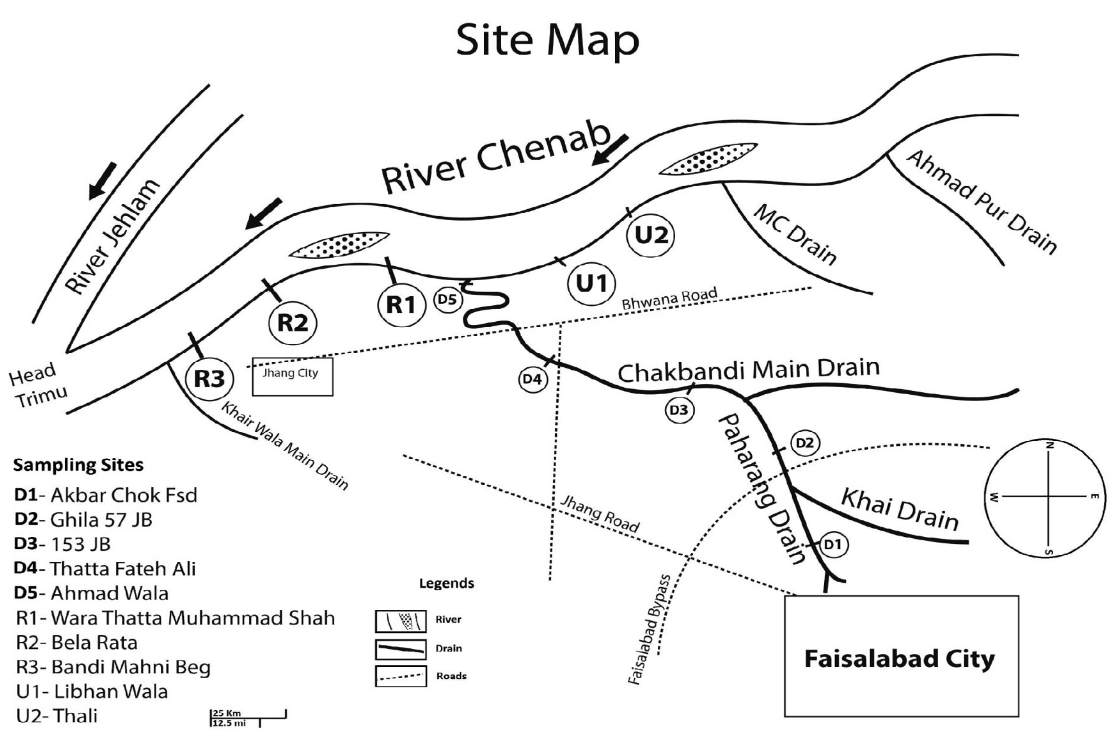

Fig. 1. Site map of the study area indicating experimental sites along the Chakbandi Main Drain and the River Chenab.

Fig. 2. Experimental sites (arrows) along the River Chenab and confluence of this dark coloured polluted water body (right) and the River Jhelum (left) at Head Trimu*, Jhang (Google source).

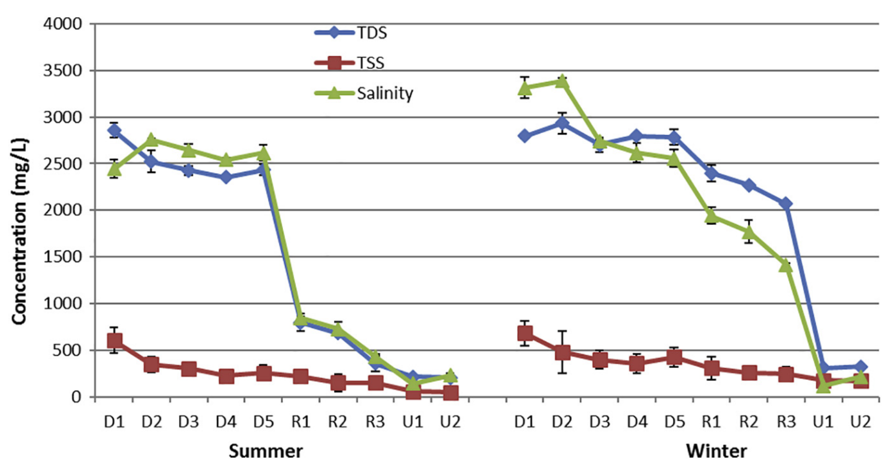

Fig. 3. Seasonal variations in the values of total dissolved solids (mg/L), total suspended solids (mg/L) and salinity (mg/L) from different experimental sites of the study area. Chakbandi Main Drain sampling sites (D1, D2, D3, D4, -D5); River Chenab Sampling sites (R1, R2, R3); Control sites (U1 and U2). Three replicates of 3 L water samples were drawn from 50 cm depth with a water sampler.

Waste-water showed the alkaline nature and an increasing trend was observed for pH along the drain in the summer months, but the non-significant decreasing trend was noticed in the river. pH was decreased in the water samples collected from the site D5, while all other parameters showed an increase in the concentration. A decreased pH was recorded in the water samples collected from the location D2 to R3 in the winter season and indicated a more alkaline nature as compared to the summer. The highest pH value was recorded as 11.79 ± 0.07 in the winter months. In both seasons the river sites (R1 to R3) showed similar alkaline nature and the difference was found only in drain wastewater in both seasons. These non-significant variations in the pH values in both seasons indicated that the sediment in the river releases pollutants even if there was a less amount of wastes disposed into the river by the tributary drains or diluted by the rain or melting glacier waters. pH was low in the water samples collected from site D1 because this site receives the major amount of domestic sewage wastes and have a smaller amount of industrial wastes. The conductivity and the phenols showed a similar pattern along the drain and the river. Only conductivity showed significant dilution at site R1. In the winter conductivity and the phenols again showed a similar pattern along the drain and the river, but comparatively higher concentrations when compared to the drain in the summer. Both of these parameters showed significantly higher concentrations in the river during the winter season indicating sedimentation in the drain and the river. Salts in water are present in the form of ions capable of conducting an electric current. Control sites U1 and U2 showed permissible values of pH, conductivity, and phenols (Fig. 4).

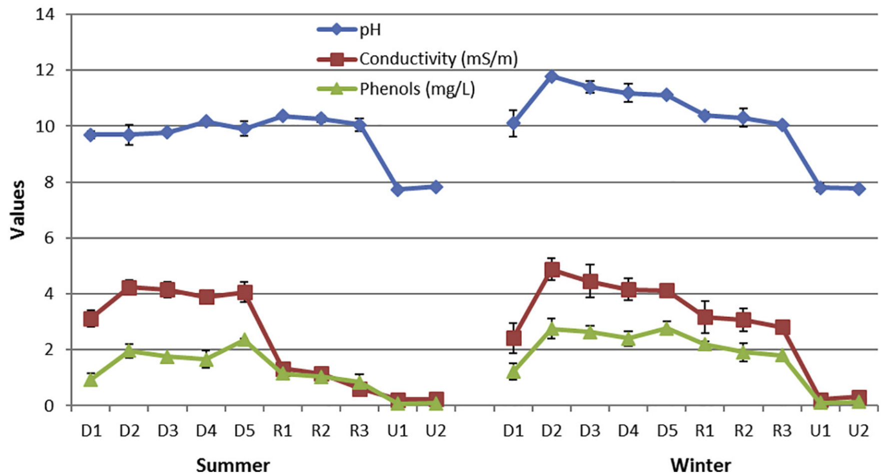

Fig. 4. Seasonal variations in the values of pH, conductivity (mS/m) and phenols (mg/L) from different experimental sites of the study area. Chakbandi Main Drain sampling sites (D1, D2, D3, D4, -D5); River Chenab Sampling sites (R1, R2, R3); Control sites (U1 and U2). Three replicates of 3 L water samples were drawn from 50 cm depth with a water sampler.

Biochemical oxygen demand (BOD) in both seasons showed similar patterns. There was a decreasing trend in BOD in the drain and the river except at the sampling site D5. Chemical oxygen demand (COD) also showed a decrease in values for all locations except at D5 where it showed an increase in values just like other parameters. Sulfates showed an increase in the concentration at location D1 and D2 and decrease in the level of sulfates from D3 and D4, again increase at D5 and then again decreasing trend was found along the river. The decrease in BOD and COD was due to the significant sedimentation of the organic matter in the drain and the river. Sulfates showed higher concentrations in the winter season as compared to the summer and indicate diminutive sedimentation in the river. All three parameters were found to be within permissible limits from control sites U1 and U2 (Fig. 5).

Heavy metals (Mn, Pb, Hg, Cu, Sn, Cr, Zn, and Cd) were found to be significantly higher in concentration than maximum permissible limits as mentioned by WHO (1992) for freshwater bodies. In the summer season, heavy metals concentrations were detected in the following order Mn > Pb > Hg > Cu > Sn > Cr > Zn > Cd and in the winter were as Pb > Mn > Cu > Hg > Cr > Sn > Zn > Cd (Fig. 6). In the summer all metals showed dilution but significantly higher dilution was recorded for Mn, Pb, and Cu. In summer, Mn, Pb, and Sn showed significant sedimentation in the drain and the river Chenab; Cd and Zn showed low sedimentation. Mercury (Hg) indicated sedimentation only in the drain while Cr and Cu do not show any sedimentation (Fig. 6). In the winter almost all metals showed a higher concentration compared to the summer season. Pb, Mn, Cr, and Cu showed one third more concentration in the winter indicating higher metal load. In the winter season, these metals were detected in almost double amounts in the water samples collected from the sampling sites (R1-R3) of the river Chenab and may probably have an effect on the abundance of aquatic fauna and flora or cause stress to it. Except for Hg, all metals showed an increasing trend from D1 to D2 and significant sedimentation in the winter season. Only Pb > Mn > Hg > Cu showed significant dilution from sampling location D5 to R1 (Fig. 6). Control sites upstream of the CBM drain entrance into the River Chenab (U1 and U2) both in the summer and the winter showed metal concentrations within permissible limits as mentioned by WHO (1992).

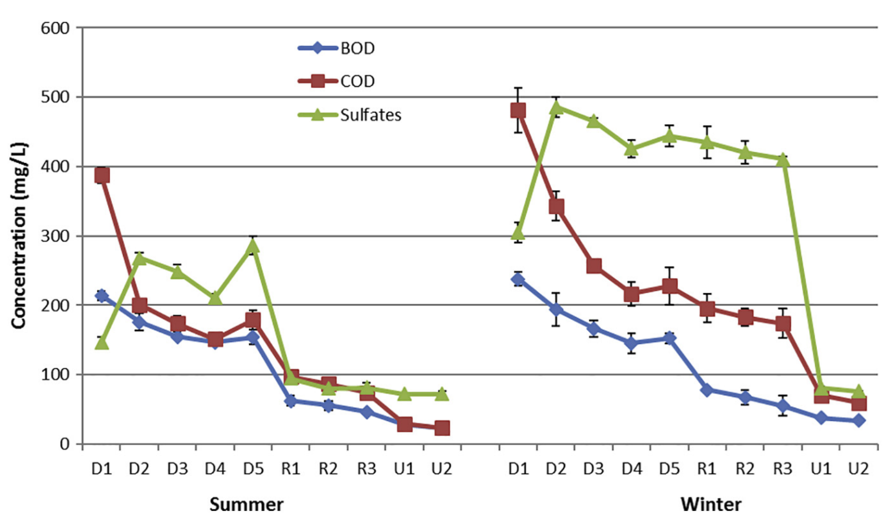

Fig. 5. Seasonal variations in the concentrations of heavy metals (mg/L) from different experimental sites of the study area. Chakbandi Main Drain sampling sites (D1, D2, D3, D4, -D5); River Chenab sampling sites (R1, R2, R3); Control sites (U1 and U2). Three replicates of 3 L water samples were drawn from 50 cm depth with a water sampler.

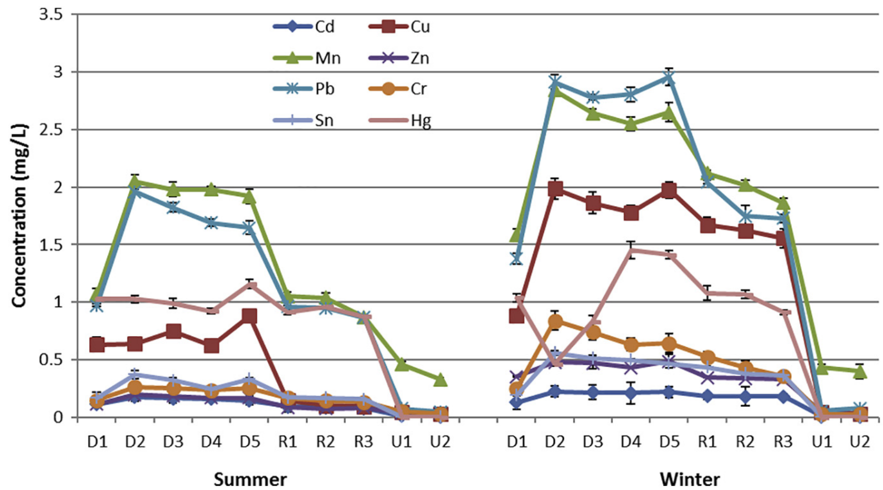

Fig. 6. Seasonal variations in the values of Cd, Cu, Mn, Zn, Pb, Cr, Sn and Hg (mg/L) from different experimental sites of the study area. Chakbandi Main Drain sampling sites (D1, D2, D3, D4, -D5); River Chenab sampling sites (R1, R2, R3); Control sites (U1 and U2). Three replicates of 3 L water samples were drawn from 50 cm depth with a water sampler.

4. Discussion

The results of this study exhibited that high sediment loads are associated with heavily disturbed Chakbandi drain reaching to River Chenab. Our results propose that rapid industrialization and other anthropogenic activities might have contributed to increasing levels of suspended solids in Chakbamdi drain and the sampling location at River Chenab. The findings of this study regarding spatio-temporal variation in water quality in the River Chenab were consistent with the findings of other reported studies (Sharma, 2003; Prasad, 2005; Zaimoglu et al., 2006). Keramat (2008) also observed higher values of TSS in waste discharge to Haraz River. Our findings of seasonal differences in TSS are in line with the findings of Adhikari and Gupta (2002) in the sewage effluent channel of Calcutta, India. Bhaskar et al. (2003) reported higher alkalinity level at specific sites on the river. Akuskar and Gaikwad (2006) reported a highly alkalinity of the river water due to the pollution in the River Torsa. The sites upstream to the waste disposal sites were found less polluted (Sharma, 2003). The conductivity of freshwater serves as a rapid measure of the TDS in water. Our findings of conductivity are in agreement with the results of previous studies (Sahu et al., 1996; Sharma, 2003; Prasad, 2005; Zaimoglu et al., 2006) who also reported higher values of conductivity in polluted waters. Similar findings of high BOD and COD were also reported by Akuskar and Gaikwad (2006), Chavan et al. (2005) and Jung et al. (2016). Pillay (2004) evident higher COD due to organic pollution from multiple sources like sewage. Gupta and Pankaj (2006) also reported that such higher values are due to anthropogenic activities. Shrivastava and Patil (2002) reported a concentration of COD as 74–154 mg/L in Tapti river and argued that this higher value was due to pollution. These values are even less than we found from River Chenab. Our findings of seasonal differences corroborate with the findings of Tripathi et al. (2008). They reported that higher COD is related to an increased volume of sewage in the Triapthi River.

Pb, Mn, Cr, and Cu showed one third more concentration in the winter indicating higher metal load. Similar findings were also reported by Thevenon et al. (2011) and Emoyan et al. (2006). Control sites upstream of the entrance of the CBM drain into the River Chenab (U1 and U2) both in the summer and the winter showed metal concentrations within permissible limits as mentioned by WHO (1992). Higher concentrations of Cu and Cr in this study area could be attributed to the chemicals used to treat wood and its products. These chemicals often comprise salts of arsenic, copper and chromium in mixed soluble forms (Ndiokwere, 2004). The higher concentration of Ni and Pb in this study may be due to industrial pollution through electric batteries, dyes, petroleum refinery, etc., and can also be due to atmospheric deposition (Merian, 1991; Robinson, 1996). The level of Zn in the study area could be attributed to other metals as zinc occurs in nature with other metals. Our findings were in line with the results of previous studies (Dallas and Day, 1993; Thevenon et al., 2011; Hamed et al., 2013; Emoyan et al., 2006). The results of this study have confirmed that untreated industrial and sewage waste disposal has made the water of the River Chenab unsuitable for the growth of aquatic flora and fauna (Gupta and Pankaj, 2006; Khangembam and Gupta, 2008; Verma and Saksena, 2010). The water quality pollution in the study area was mainly due to discharge from domestic and industrial sewage entering from the upstream. These findings were in line with a study conducted in Lake Pandu Bodhan, where high levels were reported due to anthropogenic domestic sewage activities (Solanki et al., 2010; Zhaoa et al., 2012). Furthermore, water from this freshwater body is not even suitable for agricultural purposes.

5. Conclusion

Higher values of physicochemical parameters and heavy metals in the River Chenab indicated a higher level of pollution. Although, the majority of the parameters showed significant sedimentation and dilution in the drain, still, the parameters exhibit many folds, found to be higher than the MRL values recommended by WHO (1992) for surface freshwaters. This is due to the fact that there is an untreated and unregulated discharge of toxic and contaminated effluent into open surface drains and ultimately discharged into River Chenab.

Acknowledgements

The authors (SM and ZA) would like to express their sincere appreciation to the Deanship of Scientific Research at the King Saud University for its funding of this research through the Research Group Project No. RG-1435-012. "The authors thank the Deanship of Scientific Research and RSSU at King Saud University for their technical support".

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