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Article

Impact of wastewater irrigation on major nutrient status in soil near Bhaluka industrial area of Bangladesh

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Abstract: The population increase has not only increased the fresh water demand but also increased the volume of wastewater generated. Treated or recycled wastewater (RWW) appears to be the only water resource that is increasing as other sources are dwindling. Increasing need for water has resulted in the emergence of domestic wastewater application for agriculture and its relative use. The present study was conducted at the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh during 2013 to evaluate the contribution of wastewater to major soil nutrients (N, P, K, S, Ca, Mg, B and Na) and fluctuation in physicochemical properties of soil (soil pH and Ec) from waste carrying canal at 10 selected sites of Bhaluka Upazila. Three (3) soil samples were collected at 0, 30 and 60 m distances from the waste discharging canals. The pH, EC, N, P, K, S, Ca, Mg, B and Na in soil samples decreased gradually with the increase of distance from waste discharging canal. Maximum concentrations of N at 60 and 0m distance varied from 8400 to 9700, P from 1850 to 5000, K from 4600 to 6000, S from 2000 to 4000, Ca from 7500 to 28800, Mg from 7500 to 7800, B from 90 to 2800 and Na from 2300 to 3100 µg g^{-1} in test soil.The results showed better nutrient status of the soil along waste discharge canals. The findings give applicable advice to commercial farmers and agricultural researchers for proper management and use of treated industrial wastewater for agricultural purpose.

Keywords: wastewater; major nutrients; irrigation; soil nutrient status

1. Introduction

An effluent is an inevitable production of industrial process. It is defined by the United States Environmental Protection Agency as “wastewater (treated or untreated) that flows out of a treatment plant, sewer or industrial outfall. Increased number of industries has enlarged the disposal of effluent to open land or to natural water resources. Effluent of different industries may vary in composition depending upon the source of production. Effluent may containessential nutrients and some toxic substances. The available macronutrients and micronutrients of effluents can increase soil fertility. The industrial hot-spots of Bangladesh are located near the urban and suburban areas and in many cases are surrounded by agricultural fields. The irrigation of industrial, municipal, sewage-sludge effluent and dumping of solid wastes on crop fields due to its high organic matter and nutrient content is a common scenario. As a result the untreated effluents get dispersed throughout the crop field and plants are exposed to a pool of toxic metals. Moreover, flooding causes inundation of the cultivated fields with industrial effluents. In rainy season, surface runoff and seepage contribute to the transport of heavy metals over distance along with waste disposals. In many regions of the world, particularly in water-scarce urban and peri-urban areas and where competition for water is high, wastewater is being used for agricultural purposes. While some countries implement agricultural wastewater use practices and guidelines that follow national regulations or international guidelines and safety standards, in many other countries, especially in the developing world, use of wastewater is an unregulated but common practice. The lack of implementation of guidelines and safety standards can lead to an otherwise avoidable aggravation of health risks that could result in significant secondary impacts. With increased industrialization in residential areas, different materials are discharged into effluent water which leads to environment pollution. This concern is of special importance where untreated effluent is applied for longer periods to grow vegetables in urban lands. Such uses are on the increase because the effluent contaminated waste water is a free and good source of organic matter as well as plant food nutrient, variable and cheap option for disposal (Rutkowski, 2006). As a consequence, the use of waste water and other industrial effluents for irrigating agricultural lands is on the rise particularly in peri-urban areas of developing countries. Many industries dispose of effluents via the open and covered routes into the main channels, which also carries domestic water. Farmer's fields near these channels are irrigated with these polluted effluents for raising crops. Water is a vital resource but a severely limited in most countries. Rapid industrial developmental activities and increasing population growth had declined the resources day to day throughout the world. The population increase has not only increased the fresh water demand but also increased the volume of wastewater generated. Therefore, there is an urgent need to conserve and protect fresh water and to use the water of lower quality for irrigation (Al-Rashed and Sherif, 2000). Treated or recycled wastewater (RWW) appears to be the only water resource that is increasing as other sources are dwindling (USEPA, 1992). *Bhaluka* is a newly industrial growing site of Bangladesh, which is highly susceptible to environmental pollution over last decade. There are several types of industrial units including textile, dyeing, pharmaceuticals, leather, cosmetics, aluminum, ceramic, glass, garments, packaging industry and brick fields. The untreated wastes and effluents from these industries are discharged randomly to soils, canals and in the vicinity of the industrial areas. Moreover, the polluted water is irrigated to paddy and vegetable fields. The area also suffers from flooding during rainy season. Consequently the reuse of wastewater for agriculture is highly encouraged (Mohammad and Mazahreh, 2003; Al-Salem, 1996). The reuse of wastewater for agricultural irrigation purposes reduces the amount of water that needs to be extracted from water resource (USEPA, 1992 and Gregory, 2000).It is the potential solution to reduce the freshwater demand for zero water discharge avoiding the pollution load in the receiving sources. It is the necessity of the present era to think about the existing urban wastewater disposal infrastructure, wastewater agriculture practices, quality of water used, the health implications and the level of institutional awareness of wastewater related issued. (Rutkowski, 2006).

2. Materials and Methods

2.1. Sampling procedure, preparation and preservation

All sampling were done at Bhaluka Upazila (Figure 1) during the month of February and March, 2014. Ten (10) sites near the industrial waste carrying canals were selected to provide satisfactory representation of the entire study area. Surface (0-15 cm) soil samples were collected at 0, 30 and 60 m distances from the waste discharging canals at each site. Each soil sample was air dried, and all clods and crumbs were removed and mixed uniformly. Soils were sieved through a 2-mm sieve to remove coarse particles before sub-sampling for chemical analysis. The final samples were kept in labeled polypropylene containers at ambient temperature before analysis.

2.2. Soil reaction (pH) and electrical conductivity (EC)

Soil pH was determined by using a glass electrode pH meter (WTW pH 522; Germany) as described by Jackson (1973). The electrical conductivity (EC) of collected soil samples were determined electrometrically (soil water ratio was 1:5) by a conductivity meter (WTW LF 521; Germany) as described by Anderson and Ingram (1996).

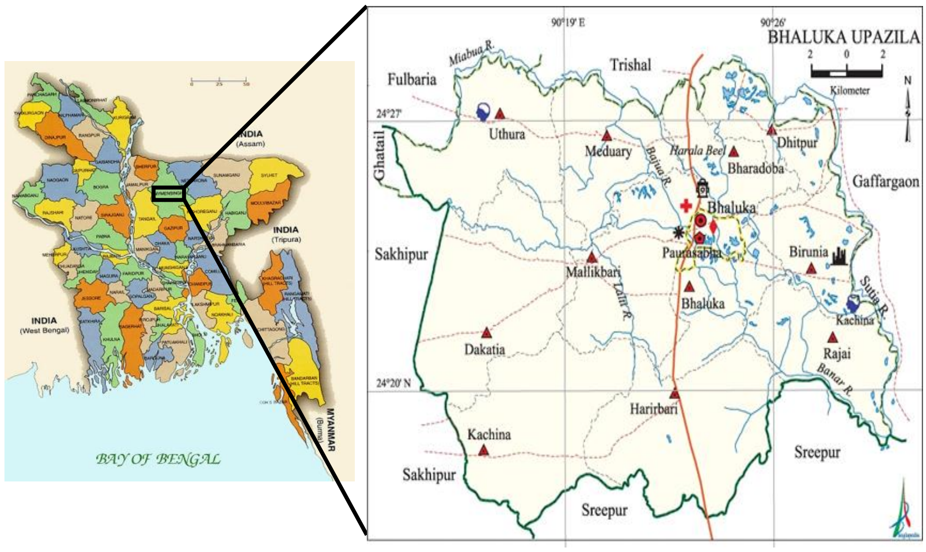

Figure 1. Map of *Bhaluka* showing the sampling sites.

2.3. Chemical analysis

Exactly 1 g soil from each sample was taken separately in 250 mL digestion tubes, then 10 ml concentrated HNO_3 was added to it. The content was kept for 16 hours at room temperature for pre digestion and then heated at 140º C for 150 mins (Tam and Yao, 1999). After that the content was cooled, diluted with deionized water and the volume was made 100 mL. All the samples were filtered through filter paper (Whatman No. 42).Calcium of soil and plant samples was determined from aliquot by complexometric method of titration using 0.01 M Na_2EDTA ($Na_2H_2C_{10}H_{12}O_8N_2.2H_2O$) as a chelating agent at pH 12 in presence of calcon indicator (Page *et al.*, 1982).Magnesium was analyzed by complexometric method of titration using 0.01 M Na_2EDTA ($Na_2H_2C_{10}H_{12}O_8N_2.2H_2O$) as complexing agent at p^H 10 in the presence of eriochrome black T (EBT) indicator (Page *et al.*, 1982).Phosphorus of the soil samples was determined colorimetrically using stannous chloride as a reductant, following the procedure stated by Jackson (1973). Phosphorus content of the aliquot was determined by spectrophotometer (Model: TG-60 U) at 660 nm wavelength. Potassium and sodium of soil and plant samples were determined from the aliquot separately with the help of flame emission spectrophotometer (Model: JENWAY-PFP7) at 589 nm and 768 nm for sodium and potassium, respectively suggested by Ghosh *et al.* (1983).Boron was determined by Azomethine-H methodAbsorbance was read at 420 nm following the instructions of Page *et al*. (1982). Nitrogen of the soil and plant samples was determined by Kjeldahl method as described by Bremner (1996).

2.4. Soil sampling sites

Table 1.Information regarding soil sampling sites at *Bhaluka*Upazilla, Bangladesh.

Sampling sites	Location	Sample ID	Distance from canal	Possible sources of contamination
Site-1	Hawaile	1a,1b,1c	0 m, 30 m, 60 m	Glass, metallurgical, textile, composite, garments industry.
Site-2	Hawaile	2a, 2b, 2c	0 m, 30 m, 60 m	Metallurgical, Pharmaceuticals, textile and ceramic industry.
Site-3	Jamirdia	3a,3b,3c	0 m, 30 m, 60 m	Textile, composite, battery acid disposal, electric industry.
Site-4	Jamirdia	4a,4b 4c	0 m, 30 m, 60 m	Electric, textile, composite industry.
Site-5	Amtoli	5a, 5b,5c	0 m, 30 m, 60 m	Ceramic, textile, composite and dyeing industry.
Site-6	Amtoli	6a, 6b, 6c	0 m, 30 m, 60 m	Dyeing, composite industry.
Site-7	Kharuali	7a, 7b, 7c	0 m, 30 m, 60 m	Pharmaceuticals, composite, textile, dyeing industry.
Site-8	Kharuali	8a, 8b, 8c	0 m, 30 m, 60 m	Pharmaceuticals, composite, textile and dyeing industry.
Site-9	Bagrapara	9a, 9b, 9c	0 m, 30 m, 60 m	Saline, dyeing industry.
Site-10	Bagrapara	10a, 10b, 10c	0 m, 30 m, 60 m	Glass, dyeing, agrochemical, and detergent industry

2.5. Statistical analysis

The statistical analyses of the analytical results obtained from the chemical analysis of different soil samples were performed using Excel Statistics version 4.0 and mean differences were made by multiple *t*-test.

3. Results and Discussion

3.1. Soil pH

The pH values of soil samples ranged from 6.91 to 7.97, 5.27 to 7.58 and 5.11 to 7.27 (at 0-15 cm depth) at 0, 30 and 60 m distance from waste canal, respectively (Figure2). The highest (7.97) and lowest (5.11) pH values were recorded at the sites Hawaile (site-1) and Bagrapara (site-9), respectively.Various materials (wastes, effluents, chemicals and salt etc.) discharged from different industries might be responsible for wide range of pH variation. Similar finding was reported by Sumi (2010) who found the pH of soil collected from Gazipur ranging from 6.63 to 7.30.

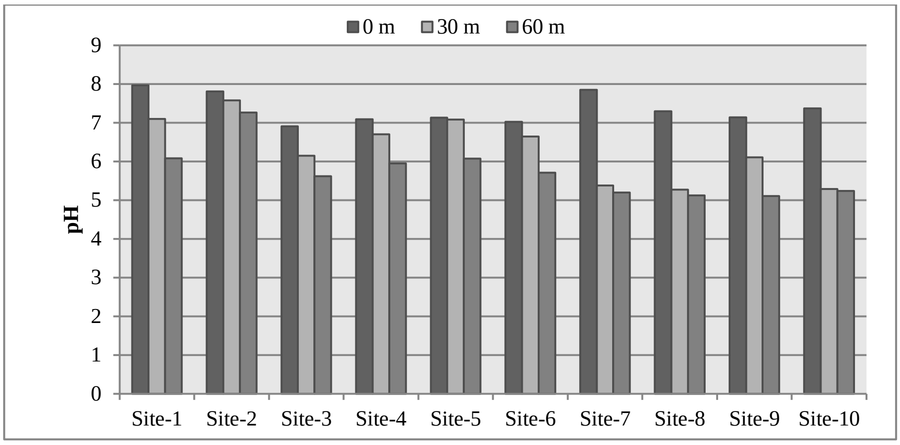

Figure 2. Soil pH at different distances.

3.2. Electrical conductivity (EC)

Like pH values of the collected samples, EC values also decreased with the increase of distance from waste discharging canal. The EC values of collected soil samples ranged from 351 to 1324, 170 to 567 and 149.4 to 447 μScm^{-1} at 0, 30 and 60 m distance from waste canal, respectively (Figure 3). The highest EC value (1324 μScm^{-1}) was obtained in soil collected at 0 m distance from the waste canal at the site Bagrapara (site-10) which is familiar as industrial waste discharge area. According to Costa *et al.* (2001), high EC value in soil, might be due to huge quantities of salt, solid wastes and effluents of tannery and other industries. In general, EC of soils varied markedly with soil salinity. The high salt affected soils of the study site account for the higher EC.

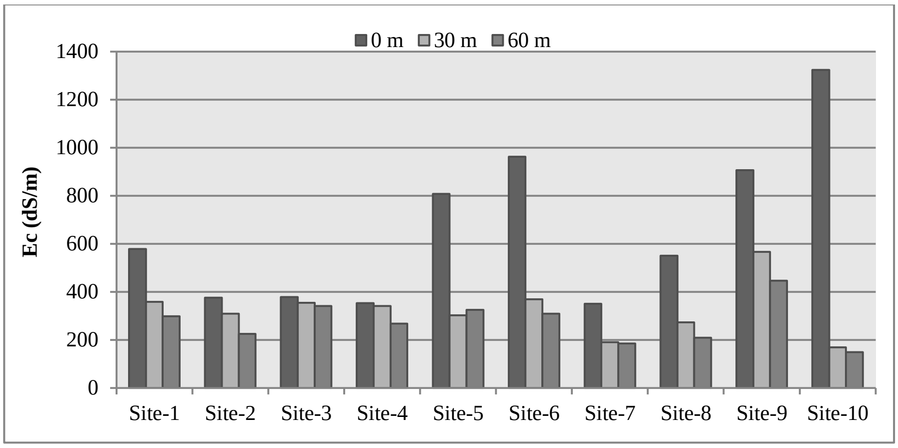

Figure 3. Soil Ec levels at different distances.

3.3. Major nutrient status in soil

3.3.1. Nitrogen

The concentration of N in almost all the soil samples was below the typical concentration (15000 $\mu g\ g^{-1}$) sufficient for plant growth as proposed by Epstein, 1965. The minimum and maximum concentration of N in soil samples were 2900 and 9700 $\mu g\ g^{-1}$, respectively (Figure 4). The mean concentrations of N were 8900, 5200 and 4900 µg g^{-1}, respectively at 0, 30 and 60 m distances. 50, 40 and 30% sites at these distances had values greater than the mean. Maximum concentration of N was obtained at Jamirdia (site-4). N content decreased from canal edge to distant places indicating its anthropogenic origin.

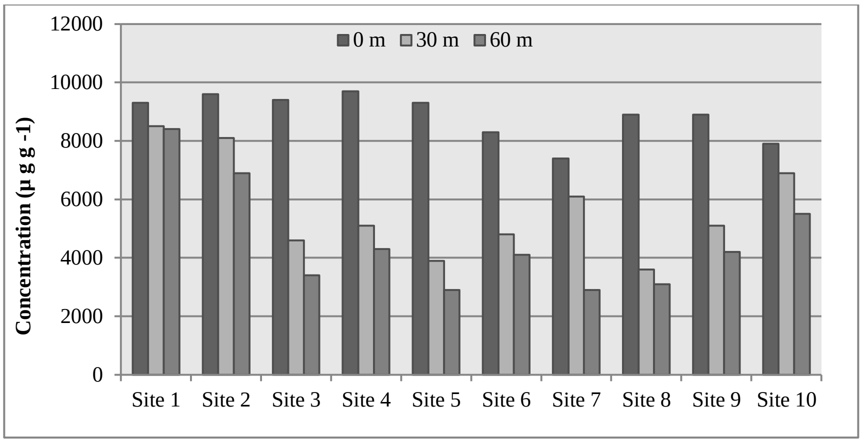

Figure 4. Pattern of N concentration in soil at different distances.

3.3.2. Calcium, Magnesium and Sulphur

The content of Ca in soil samples collected at 0 m distance from waste canal varied from 7200 to 28800 µg g^{-1} with an average value of 17700. At 30 and 60 m distances, the Ca content varied from 4000 to 19200 and 1700 to 7500 with mean values of 7800 and 3400 µg g^{-1}, respectively. About 60% samples at 0 m, 20% at 30 m and 30% at 60 m distance from pollution site had Ca above the mean values and the rest were below the mean. The highest Ca content was observed at Hawaile (site-2).It indicates the anthropogenic load of Ca in the soils of present study area. The high concentration of calcium in soils at the canal side might be due to discharge of industrial wastes to the canal from the industrial area. The concentration of Mg in soil was detected within the range of 3800 to 7800 having a mean value of 4600 µg g^{-1} at 0 m distance from waste canal. At 30 and 60 m distances from waste canal, Mg concentration varied from 2800 to 7400 and 1700 to 7500 with mean values 3600 and 3400 µg g^{-1}, respectively. The result showed that 20, 10 and 30% samples at 0, 30 and 60 m distance had values greater than the mean, respectively. Maximum concentration of Mg was found at Bagrapara (site-10). Mg content decreased gradually with the increase of distance from waste canal. The variations in Mg content might also be due to deposition of industrial wastes, origin and nature of parent materials and cultural practices done by the farmers. The concentration of sulphur in soil varied from 600 to 4000, 300 to 2200 and 300 to 2000 µg g^{-1} at 0, 30 and 60 m distances from waste canal with mean values of 1900, 1100 and 800 µg g^{-1}, respectively (Figure 5). 40% samples at both 0 and 30 m, 30% samples at 60 m distance from waste canal had values greater than the mean. The highest and lowest amount of S was found at Bagrapara (site-10) and Hawaile (site-2), respectively. All sites showed a gradual decrease in soil S content with the increase of distance from waste canal which indicates the anthropogenic load of S at those sites, preferably from industrial activities. Detergent and agrochemical industries might have been responsible for this S.

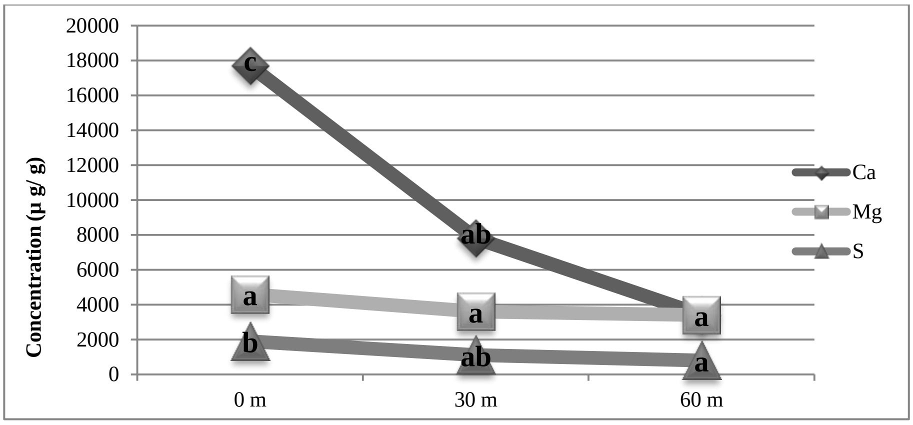

Figure 5. Mean concentration of Ca, Mg and S at 0, 30 and 60 m distances.

3.3.3. Phosphorus, Potassium, Boron and Sodium

The minimum and maximum phosphorus content in soil was 430 and 5000 µg g^{-1}, respectively. The mean values of P at 0, 30 and 60 m distances from waste canal were 1330, 1160 and 950 µg g^{-1}, respectively. The result indicates the industrial origin of P in the soils of the study area. This P might have originated from the glass and fertilizer industry of the study area. The mean K content decreased gradually with the increase of distance from waste carrying canal. This indicates the anthropogenic load of K in the study area. K content in the soil samples ranged from 3000 to 6000, 600 to 5500 and 3000 to 4600 µg g^{-1} at 0, 30 and 60 m distances, respectively with mean values of 4100, 3800 and 3500 µg g^{-1}(Figure 6). The concentrations of K at 50, 60 and 30% sites from 0, 30 and 60 m distances, respectively were greater than the mean values. The highest level of K was observed at Hawaile (site-2). The concentration of B was detected within the range of 50 to 2800 µg g^{-1} having a mean value of 420µg g^{-1} at 0 m distance from waste canal. At 30 and 60 m distances, B concentration varied from trace to 120 and trace to 90 with mean values 90 and 70 µg g^{-1}, respectively. The result showed that 10, 60 and 50% samples at 0, 30 and 60 m distances, respectively had values greater than the mean. Maximum concentration of B was found at the site Kharuali (site-7). B content in soil varied greatly and it crossed the maximum limit for crop production at some sites. High B content in soil may hamper the rice production in the study area. There was a decreasing trend in Na concentration in the soil samples with increasing distance from waste canal. Dissemination of Na to nearby soils may change soil physical and chemical quality. The concentration of Na varied from 1400 to 3100, 1400 to 2300 and 500 to 2300 µg g^{-1} with a mean value of 2300, 1900 and 1600 µg g^{-1}, respectively at 0, 30 and 60 m distances from waste canal. Out of 10 sites, 3 sites at the nearest spot, 6 sites at each of 30 and 60 m distances from waste canal had values greater than the mean. The highest concentration of Na was found at Bagrapara (site 9).

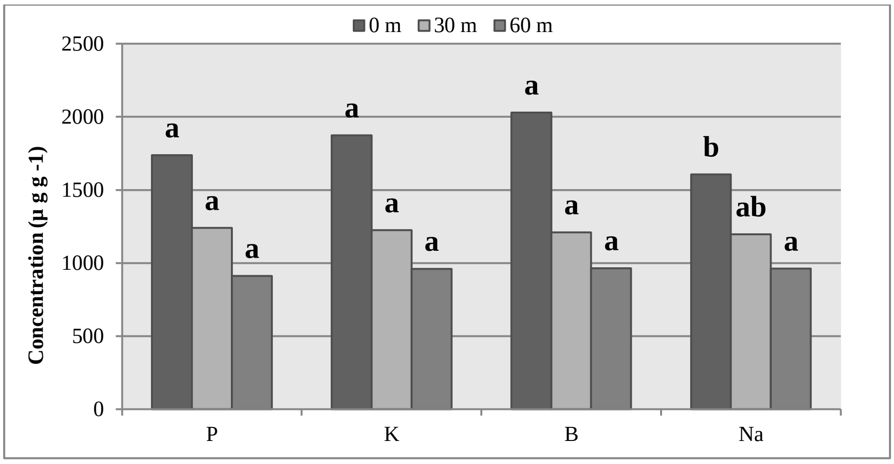

Figure 6. Mean concentration of P, K, B and Na at 0, 30 and 60 m distances.

4. Conclusions

Wastewater from the *Bhaluka* industrial area canals can be a source of fertilizer since it contributes N, P, K, S, Ca, Mg and organic matter without negative effects regarding changes in soil pH. However, an additional contribution of nitrogenous fertilizer would be needed to obtain suitable crop growth. It is necessary to be aware that many crops could suffer from the negative effects of wastewater irrigation due to its sodium and boron content. Nonetheless, the benefits of irrigation with wastewater should be kept in mind, including the addition of plant nutrients to rice plants and the conservation of soil health. Additional studies are required to assess the long-term effect of uncontrolled waste disposal in canals near agricultural land and assess the risk for soil contamination by toxic elements like heavy metals, radioactive materials etc. Particular interest should also be paid to reduce soil EC levels for successful crop production.

Conflict of interest

None to declare.

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