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RESEARCH NOTES

Assessment of Water Quality of Huluka and Alaltu Rivers of Ambo, Ethiopia

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ABSTRACT

The physico-chemical parameters, nutrient status and heavy metal ions of Huluka and Alaltu Rivers of Ambo, Ethiopia were studied. Temperature, pH, electrical conductivity, CO_2 content, total dissolved solids, hardness, dissolved oxygen, Ca^{2+}, Mg^{2+}, Cl^-, nitrate, phosphate and sulphate have been determined along with selected heavy metals to assess the various water quality profiles along the rivers due to addition of various waste materials through anthropogenic activities. The majority of the parameters show an increasing trend progressing downstream and the declining quality of the rivers. The downstream samples have shown almost a three times increase in most of the measured physico-chemical parameters but fell within the recommended limits for drinking water except for dissolved oxygen and phosphate. Along the river course, most of the heavy metals fulfill the maximum permissible limit for drinking water according to the international standards except Cd and Mn.

Keywords: Ethiopia**,** Heavy metals, Huluka and Alatu Rivers, physico-chemical parameters, Water quality.

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INTRODUCTION

Rising over 70% of the Earth's surface, water is undoubtedly the most precious natural resource that exists on our planet. Without the seemingly invaluable compound comprised of hydrogen and oxygen, life on Earth would be non-existent: it is essential for everything on our planet to grow and prosper (Tadesse, 2005). Although we as humans recognize this fact, we disregard it by polluting our rivers, lakes, and oceans. Subsequently, we are slowly but surely harming our planet to the point where organisms are dying at a very alarming rate. In addition to innocent organisms dying off, our drinking water has become greatly affected as is our ability to use water for recreational purposes. In order to combat water pollution, we must understand the problems and become part of the solution. Water quality is closely linked to water use and to the state of economic development. In industrialized countries, bacterial contamination of surface water caused serious health problems in major cities throughout the mid-1800s. By the turn of the century, developed countries began building sewer networks to route domestic wastes downstream of water intakes. While waterborne diseases have been eliminated in the developed world, outbreaks of cholera and other similar diseases still occur with alarming frequency in developing countries.

Most of our water resources are gradually becoming polluted due to the addition of foreign materials from their surroundings

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(Lokeshwari and Chandrappa, 2006). Human habitatation on riverbanks is responsible for the discharge of sewage wastewaters into the river stream, which the entire pollute length of the river. Industrial units located in and around the outskirts of the city, intensive agricultural practices along the riversides and indiscriminate disposal of these sewage wastewaters are the major sources of river pollution (Melaku *et al*., 2005). In developing nations, more than 95 percent of urban sewage is discharged untreated into rivers and bays, creating a major human health hazard. Use of this polluted wastewater for irrigation without any treatment causes soil and groundwater pollution, which leads to both qualitative and quantitative losses and urban water pollution is growing at alarmingly faster rates (Melaku *et al*., 2007).

In aquatic systems, the natural concentrations of metal ions are principally dependent on the ambient distribution, weathering and leaching of the elements from the soil in the catchment area, while heavy metals are carried to the lakes through atmospheric deposition and other manmade activities. The characteristics of the water, such as acidity and the amount of organic matter, are known to be important factors in determining the fate of heavy metals in lakes (Mannio *et al*., 1993; Skjelkvale *et al*., 2001; Tulonen *et al*., 2006). Increased loading of heavy metals into aquatic systems may have several ecological consequences. Elevated trace metal concentrations may lead, for example, to toxic effects or biomagnifications in the aquatic environment. Accumulation of heavy metals in the food web can occur either by bio-concentration from the surrounding medium such as water or sediment, or by bioaccumulation from the food source.

The Huluka and Alaltu Rivers of Ambo, Ethiopia, receive discharges from domestic sources and are subject to intensive exploitation by domestic and agricultural activities. Such activities often introduce nutrients and potentially hazardous trace metal ions into the riverine ecosystem. Despite their foul odour and contamination, the rivers are still used for various purposes including irrigation, swimming and washing cattle. Only a few reports dealing with the quality of these river waters have appeared in the literature. In view of this fact extensive physio-chemical analysis along with major ions, nutrients and selected heavy metals were conducted on the Huluka and Alaltu water samples. These observations may reveal the absence of policies protecting water systems and/ or overt monitoring studies on Huluka and Alaltu Rivers with a view to assessing temporal variations and thereby creating public awareness.

MATERIALS AND METHODS

Geography of the Study Area

Ambo is one of the largest developing

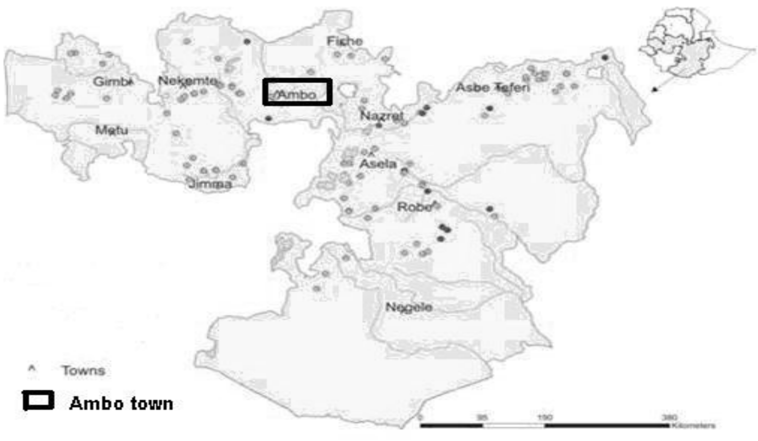

Figure 1. Location of Ambo town in Oromia regional state**.**

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towns in West Shoa zone of Oromia region in Ethiopia, located 110 km to the West of Addis Ababa, the capital city (Figure 1). The town has three *kebeles* with a population of approximately 65000. It is endowed with two major rivers, one of which separates the town into two major parts known as Huluka River which starts from Dendi Lake near Wonchi town, 39 km from Ambo, and flows from the southern pole of Ambo towards the northern part of the town. The water content of the river varies from season to season with a mean flow of about 15000 and 75,000 m^3 during the dry and rainy seasons, respectively. Alatu River originates from Ginchi town and flows from the southern pole of Ambo towards the West of the town with a mean flow of about 5,000 to 28,000 m^3 (Awulachew *et al*., 2007) during the dry and rainy seasons, respectively with many tributaries filling the river in the rainy season. In rural areas, these river waters are used for drinking, sanitation, livestock and agricultural purposes. Sewage from residential areas near these rivers is allowed to enter directly and dense weeds have occupied the sides of rivers, thus affecting the flow and photosynthesis process.

Climate

Despite its proximity to the equator, Ambo enjoys a mild, Afro-Alpine temperate and warm temperate climate. The lowest and highest annual average temperature are between 13 and 27°C. April and May are the driest months. The main rainy season occurs between mid June and mid-September, which is responsible for 70% of the annual average rainfall of 1,100 mm. It is characterized by intense rainfall of short duration. During the dry season the days are pleasantly warm and the nights are cool. During the rainy season both days and nights are cool.

Sampling Locations

The five sampling sites in Huluka and Alaltu Rivers are designated as S1 to S5 and they reflect different activities along the watercourse of the rivers (Figure 2). Sampling site S1 represents the upper stream where the rivers enter the town and S5 represents the downstream of the rivers ending at Ambo; sampling sites S2 to S4 had been selected between S1 and S5. The sampling sites were selected based on access, safety, potential sources of pollution and waste disposal activities. These sites were evenly distributed along the course of Huluka and Alaltu Rivers with more

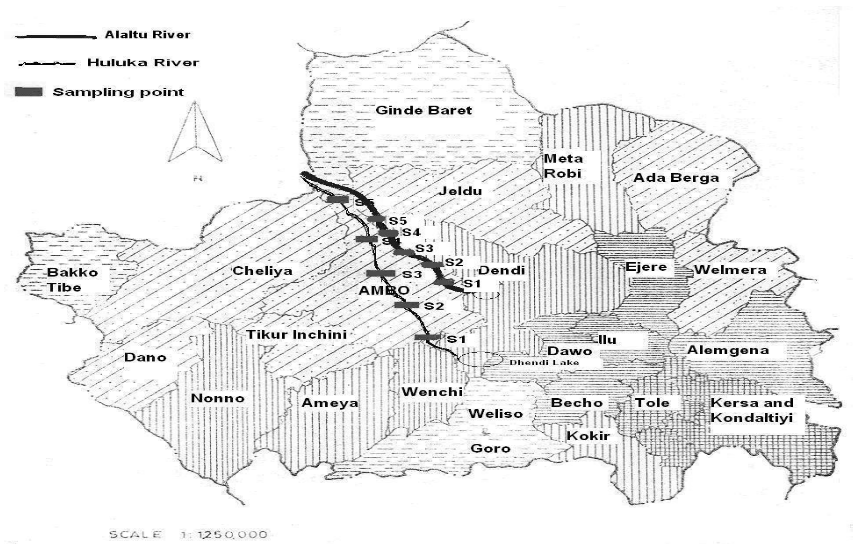

Figure 2. Map showing sampling points.

emphasis placed on polluted sites.

Samplings were carried out during the dry (March) and rainy seasons (June), 2008. Grab water samples (number of samples collected n= 5) were collected in polyethylene cans and transported to the Department of Biology, Ambo University College, for further characterization. The samples were analysed for pH, EC, temperature, CO_2, TDS, hardness ($CaCO_3$), DO, Ca, Mg, SO_4, NO_3, PO_4 etc., using the standard methods

Samplings

for the examination of wastewater outlined in the APHA (1992) manual guidelines. Among heavy metals, Fe, Cd, Co, Cu, Zn and Mn were selected and analyzed as per the standard methods cited in the APHA manual using an Atomic absorption spectrophotometer. All the chemicals and reagents used in the experiments were of analytical grade. All the results were statistically significant at $P< 0.05$.

RESULTS AND DISCUSSION

The results of the physico-chemical analysis of water samples from Huluka and Alaltu Rivers are summarized in Tables 1 and 2, respectively. The temperature of both the river water samples analysed ranged from 23.0 to 16.2 and 23.1 to 17.5°C, respectively and they were found to be above the maximum permissible limit of the Canadian Council of Ministers for Environment (CCME, 1999) guidelines for community water use. The pH (hydrogen ion concentration) of both the rivers is slightly

Table 1. Physico-chemical characteristics of Huluka River water.

Water quality	Sampling sites										Desirable standards (WHO)
	Dry season (March)					Rainy season (June)					
	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5	
Temperature (^{0}C)	22.7	22.8	23.0	22.8	22.4	17.2	17.5	17.8	16.2	16.2	15 (CCME)
pH	7.91	7.95	8.04	8.10	8.18	7.42	7.45	7.58	7.81	8.03	6.5-8.5
EC (µS cm^{-1})	175.1	178.2	388.1	588.4	580.6	140.2	155.1	380.5	515.3	540.7	1500
CO_2 (mg L^{-1})	4	8	8	10	15	3	5	8	10	14	-
TDS (mg L^{-1})	113.8	115.8	252.3	382.5	377.4	91.1	100.8	247.3	334.9	351.5	1000
Hardness (mg L^{-1} $CaCO_3$)	48	49	83	88	91	38	46	74	80	88	400
DO (mg L^{-1})	6.4	5.4	4.2	4.1	3.5	7.8	6.8	5.2	4.8	4.1	4.5-7.5
Ca^{2+} (mg L^{-1})	25	38	60	65	75	14	25	56	60	74	200
Mg^{2+} (mg L^{-1})	16	22	40	48	60	5.8	18	38.1	41.2	55.3	100
Cl^- (mg L^{-1})	18.5	25.6	38.4	48.2	60.8	13.2	18.9	30.1	41.6	50.3	400
Nitrate -NO_3^- (mg L^{-1})	0.88	0.98	1.45	1.91	2.8	1.20	1.32	1.48	2.43	3.50	25 (EC)
Phosphate – PO_4^{3-}(mg L^{-1})	0.28	0.31	0.85	0.96	1.58	0.31	0.40	1.03	1.28	1.88	0.35 (EC)
Sulphate – SO_4^{2-} (mg L^{-1})	22.4	26.2	28.0	34.0	40.1	24.1	28.8	32.0	38.5	48.9	<1000

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alkaline (Tables 1 and 2). During the rainy season the pH was at its minimum and dry season it was at the maximum. The slight alkalinity could possibly be from calcium bedrock weathering or may reflect the importance of dissolution of limestone and dolomites in the watershed and it is in confirmation of an earlier study of Melaku *et al*. (2007) on Tinishu Akaki River (TAR). The pH was low at the entry point of both rivers to the town (S1) and increases along the downstream (S5). The increase might be due to the addition of sewage wastewater, and a pH value greater than 8 at the extreme downstream sampling point (S5) may possibly be due to the presence of free ammonia, which is likely to pose problems when the water is used by downstream users for drinking and fishing. Ammonia is much more toxic in alkaline waters than in acidic ones because free ammonia at high pH values is more toxic to aquatic biota than when it is in the oxidized form (Leta *et al*., 2003). But all the values of pH are within the limit of the CCME and WHO guidelines for livestock watering and for irrigation. Electrical conductivity of water is a useful and easy indicator of its salinity or total salt content and the values for the Huluka's water ranged between 175.1 to 580.6 and 140.2 to 540.7 µS cm^{-1} during dry and rainy seasons, respectively; whereas for Alaltu River it ranged between 497.0 to 788.4 and 398.2 to 712.6 µS cm^{-1}. This is well below the WHO guideline value prescribed for drinking purposes (1,500 µS cm^{-1}). Generally, the increase in EC is recorded from up (S1) to downstream (S5) in both the rivers due to the discharge of domestic and sewage waste water and also due to enrichment of electrolytes, possibly due to the phenomenon of mineralization or weathering of sediments. These results were supported by Malairajan *et al*. (2008). The downstream water quality is strongly degraded and results in low dissolved oxygen and high conductivity.

There was a marked increase in the CO_2 content of both rivers from upstream to

Table 2. Physico-chemical characteristics of Alaltu River water

Water quality parameters	Sampling sites										Desirable standards (WHO [a])
	Dry season (March)					Rainy season (June)					
	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5	
Temperature (°C)	23.0	23.1	23.0	22.5	22.8	18.1	17.5	18.0	18.1	17.8	15 (CCME [b])
pH	7.26	7.70	7.79	7.85	8.27	7.01	7.25	7.30	7.56	8.12	6.5-8.5
EC [c] (µS cm^{-1})	497.0	514.0	566.3	760.1	788.4	398.2	485.3	514.7	688.0	712.6	1500
CO_2 (mgL^{-1})	3	4	4	6	8	3	3	4	4	5	-
TDS (mgL^{-1})	323.1	334.1	368.2	494.1	512.5	258.8	315.4	334.6	447.2	463.2	1000
Hardness (mgL^{-1}$CaCO_3$)	78	85	108	120	140	58	66	79	98	121	400
DO (mgL^{-1})	5.55	5.0	4.9	4.2	3.85	6.2	6.1	5.4	5.1	4.9	4.5-7.5
Ca^{2+} (mgL^{-1})	40	42	58	64	80	30	35	42	51	69	200
Mg^{2+} (mgL^{-1})	22	28	37	48	61	18	20	28	35	42	100
Cl^- (mgL^{-1})	27.5	38.1	51.4	62.6	73.5	21.5	32.1	41.0	51.5	65.3	400
Nitrate -NO_3^- (mgL^{-1})	0.95	1.21	1.71	2.24	3.1	1.22	1.47	2.04	2.67	3.88	25 (EC)
Phosphate – PO_4^{3-}(mgL^{-1})	0.43	0.56	0.99	1.18	1.75	0.55	0.65	1.37	1.47	1.90	0.35 (EC)
Sulphate – SO_4^{2-} (mgL^{-1})	28.1	38.4	41.5	48.7	55.9	32.1	35.3	42.0	51.1	58.9	<1000

[a] World Health Organization; [b] Canadian Council of Minister for Environment, [c] European community.
Note: the analytical results were statistically significant at $P< 0.05$.

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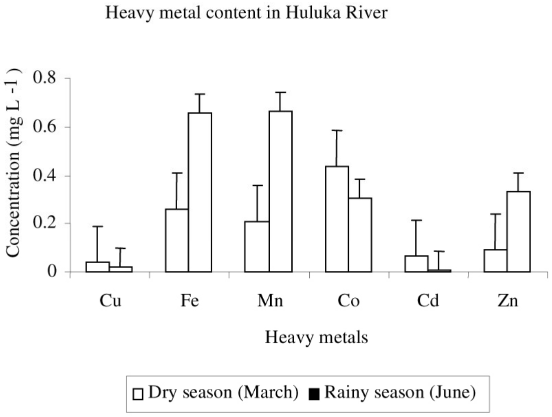
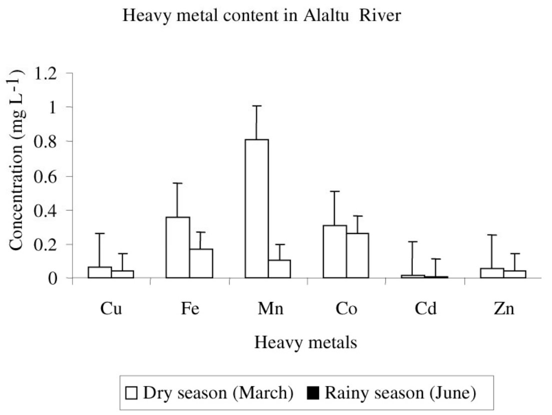
downstream in both the seasons (Tables 1 and 2). The Total Dissolved Solids (TDS) is an important parameter in evaluating the suitability of water for irrigation since the solids might clog both pores and components of water distribution system. The TDS present in the water affects its aesthetic value as well as its physico-chemical properties (Malairajan *et al*. 2008). The TDS values of Huluka River (113.8-382.5 and 91.5 to 351.5 mg L^{-1}) during the dry and rainy seasons, respectively, were also below the drinking water standard (1000 mg L^{-1}). This is applicable to Alaltu River too. The maximum values were obtained downstream as compared to upstream during both seasons. The increase in TDS can be related to pollution through a discharge of domestic and sewage waste water into Huluka and Alaltu Rivers. Although all the TDS values were higher than normal water, they found were to be within the CCME guidelines for drinking water i.e. 500 mg L^{-1} (CCME, 1999). An increase in water hardness generally decreases metal toxicity, possibly due to Ca competition on the cell surface (Gueguen *et al.,* 2004). The total hardness of water samples in the Huluka and Alaltu Rivers was found to be within the maximum permissible limit of WHO, i.e. 400 mg L^{-1}.

Dissolved oxygen (DO) is essential for all organisms in any water bodies and, in the present study, its concentration decreases from upstream to downstream in the rivers which is an indication of worsening water quality. Except for the upstream (S1), all other samples were found to be critically low and do not fulfill the CCME guideline for the protection of aquatic life i.e., 5.5-9.5 mg L^{-1}. A similar result was also reported for Lake Naivasha in Kenya (Njenga *et al*., 2003).

The Ca^{2+} and Mg^{2+} ion concentrations exhibited an increase from S1 to S5 (Tables 1 and 2) in both rivers. The base cations are associated with weathering of the bedrock and groundwater discharges with the extent of weathering linked to the reactivity of the rock, the surface area of contact between the rock and the river water (Jarvie *et al*., 1997). The chloride ion concentration in both rivers is found to be from 13.2 to 73.5 mg L^{-1} and is within the permissible limit of the CCME guideline for use as irrigation water and the limit fixed by EPA, (2003) for domestic purpose. The possible sources of chloride could be domestic and municipal sewage water. The chloride concentration in downstream samples was four times higher than the upstream samples and denotes the contamination of river water through domestic and sewage water intrusion. The nitrate concentration was found to be less than the maximum concentration of nitrate for public water supplies i.e.45 mg L^{-1} (WHO). The European Community guidelines for drinking water quality provide a reference value of 25 mg L^{-1} and maximum admissible limit of 50 mg L^{-1} for nitrate. Though the values are within the maximum permissible limits but there was an increase from upstream to downstream. A high concentration of nitrate in drinking water is reported to cause blue baby syndrome (Tufuor *et al*., 2007). The phosphate concentration of the Huluka River at water sampling sites S1 and S2 is less than the permissible EC limit (0.35 mg L^{-1}), whereas all other samples including Alaltu River have values above the permissible limit. The increase in nitrate and phosphate content could be related to urban and/or agricultural activities (mainly from fertilizers), sewage effluents and the use of phosphate additives in detergent formulations. The latter can be eroded into the river system during the disposal of wastewaters generated domestically and municipally (Melaku *et al*., 2007). The sulfate ion content in the rivers during both seasons is within the limit given by CCME for livestock use i.e. 1,000 mg L^{-1}. The main sources of sulfate ion in the river water are dissolution of evaporates such as gypsum, oxidation of sulfides and atmospheric input (Melaku *et al*., 2007). Elevated concentrations of these ions are characteristic of domestic and municipal sewage water and care (treatment) should be taken before release into the receiving Huluka and Alaltu Rivers. Though national standards for water quality management in Ethiopia are in the process of being adopted, the direct discharge of these contaminants into the downstream of both Huluka and Alaltu Rivers has definite negative



(A)



(B)

Figures 3A and 3B. Heavy metal content in Huluka and Alaltu Rivers.

effects on the river water quality as well as causing serious harm to the aquatic life and the downstream users.

The concentration of Cu, Fe, Mn, Co, Cd and Zn were determined in water samples from both rivers during the dry and rainy seasons. The analytical results are presented in Figures 3A and B. The drinking/irrigation water standards (WHO, 1984) for Cu, Fe, Mn, Co, Cd and Zn are 2.0, 1.0, 0.5, 0.2 (irrigation), 0.003 and 5.0 mg L^{-1}, respectively (WHO, 1984). The results indicate that, except for Cd, Co and Mn, all other heavy metals are well within the allowable concentrations for drinking and/or irrigation water.

CONCLUSIONS

The different physico-chemical and nutrient parameters of Huluka and Alaltu Rivers measured indicate their quality profile for various water uses from upstream to downstream**.** The water quality of the rivers shows a pattern of behavior linked to human pressure associated with domestic, municipal sewage wastewater and agricultural activities. Almost all the measured ions showed an increasing trend from upstream to downstream and deterioration of the water quality of Huluka and Alaltu Rivers.

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ارزیابی کیفیت آب رودخانه‌های آلالتو و هوموکا در آمبوی اتیوپی

س. پرابو، ل. ووندمیو و م. تیسو

چکیده

پارامترهای فیزیکو شیمیایی، وضعیت مواد مغذی و یون فلزات سنگین رودخانه‌های هولوکا (Huluka) و آلالتو (Alalto) واقع در آمبوی اتیوپی مورد مطالعه قرار گرفت. بمنظور ارزیابی کیفیت نیمرخ عرضی آب در طول رودخانه‌های فوق که بدلیل اضافه شدن پسماندهای فعالیت‌های انسانی آلوده شده‌اند، پارامترهایی از قبیل دما، اسیدیته (PH)، هدایت الکتریکی، میزان دی‌اکسید کربن (CO2)، کل جامدات محلول، سختی، اکسیژن محلول، Ca^{2+}، Mg^{2+}، Cl^{-}، نیترات، فسفات، سولفات و تعدادی فلزات سنگین تعیین شده است. اکثر پارامترها روندی رو به افزایش را در پایین‌دست و کاهش کیفیت آب را نشان داد. نمونه‌های پایین دست در اکثر پارامترهای فیزیکو شیمیایی افزایش ۳ برابری داشت و به جز اکسیژن و فسفات محلول باقی پارامترها در محدوده مجاز پیشنهاد شده برای آب آشامیدنی قرار گرفتند. با توجه به استانداردها بین‌المللی، در مسیر رودخانه اکثر فلزات سنگین به جز کادمیوم (Cd) و منگنز (Mn) دارای حداکثر مقدار مجاز بودند.

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