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Physicochemical Profile of Sludge – Wood Sawdust Compost

Emmanuel U. Dan[1]*, Solomon E. Shuaibu[1], Opeyemi K. Fatunla[2], Victor F. Ekpo[1]

[1]Department of Chemistry, University of Uyo, Akwa Ibom State, Nigeria
[2]Department of Microbiology, University of Uyo, Akwa Ibom State, Nigeria

Abstract Physicochemical properties of compost resulting from mixture of sludge from water treatment plant in Nigeria and wood sawdust were investigated using scientific methods. Physicochemical, nutrient, essential and trace element levels of raw sludge and wood sawdust used in composting indicated varied pH , total organic carbon, moisture and ash content, organic matter, nitrogen, nitrate, sulphate, chloride, phosphate, essential (K, Mg, Ca, Na, Fe) elements, and trace metals (Cr, Zn, Ca, Cd, Co). Compost obtained after 40 days indicated increased ash and moisture content, organic matter, but reduced C/N ratio and nitrogen. The nutrient of the final compost indicated increased chloride, while sulphate, ammonium ion, phosphate, nitrate decreased after 40 days. Results of essential elements and trace metals level of the final compost and raw sludge varied significantly with those of the final compost showing lower values than those of the raw sludge. Cr, Cu, and Zn levels in the final compost recorded lower abundances when compared with allowable limit for trace metals in either compost class A or B recommended for agricultural utilization by United State Environmental Protection Agency. Cd and Co levels in the final compost were not detected. However, the results reveal that the final compost obtained were rich in nutrients needed by plants for growth.

Keywords Water treatment plant, sludge, traces metals, compost

Introduction

The problem of waste generation, control and management has become a well known phenomenon in a typical Nigerian city. It has been estimated that municipal solid waste generated in atypical Nigerian city could be as high as four million tonnes, including about half a million of untreated industrial wastes [1]. The average waste generation rate in Abuja for instance, is estimated to be between 0.55—0.58 kg per person per day [2]. With the recent establishment of a major wastewater treatment plant in the city, this estimation is expected to triple in few years to come with addition of several tonnes of sewage sludge. Ademoroti [3] had estimated higher waste generation rate in some other cities. Aside from technological setbacks, this problem is further complicated by political, economic and social factors [4] and only requires a cross-cutting approach for effective abatement.

Soils provide, support and regulate fundamental processes in the environment, including nutrient cycling, plant growth, and have a strong influence on ensuring purity of the atmosphere, as well as water supply and quality. Through the delivery of these ecosystem services, vital global biodiversity and, ultimately, the sustenance of the human population is maintained.

However, over exploitation of soils through intensive agricultural practices such as the over application of phosphorus and nitrogen fertilisers has resulted in their degradation and, as a result, a diminishment of soil fertility, threatening future global food security. Phosphorus is a vital, non-renewable element required for crop growth, upon which agriculture is now almost entirely dependent to maintain current levels of food production. The extraction and processing of phosphorus, is also extremely environmentally damaging, and originates from a non-renewable source for which demand is rapidly increasing with no alternative available in the volume required. The production of nitrogen fertiliser is also a highly energy intensive and unsustainable process, tied strongly to price and availability of fossil fuels. The aforementioned situation necessitated the search for an alternative especially now the world is turning toward green technology.

Sewage sludge is formed during mechanical, biological and chemical sewage treatment. Most often sludge content does not exceed 2% of the effluent sewage volume; however, we observed tendencies to build new sewage treatment plants or to develop those already existing. This causes the generation of large amounts of sewage sludge and the problem of its management becomes a growing problem [5, 6]. Sewage sludge obtained as a by-product reflects the chemical composition of the treated sewage, but the composition of sewage itself is determined by the industrial wastewater inflow to the treatment catchment. Quantitative and qualitative composition of the sewage sludge is very complicated. It is rich in organic matter, nitrogen, phosphorus, calcium, magnesium, sulphur and other microelements necessary for plants and soil fauna to live. So it is characterized by the large manurial and soil-forming value [7]. Except the indispensable elements to live, sludge can contain toxic compounds (heavy metals, pesticides) and pathogenic organisms (bacteria, eggs of parasites).

Sludge from waste water treatment plants, apart from being used as plant fertilizer and soil conditioner, have been reported to help in the reduction of N_2O emissions when applied to soils, perhaps due to increases in soil aeration [8], both increased [9, 10, 11] and decreased CO_2 emissions [12] have been reported from biochar-amended soils, CH_4 emission from soil may be either enhanced or suppressed by biochar addition [12, 9]. Composting has been reported to excel over other conventional methods of processing sludge with respect to fuel economy, nutrient recovery, and control of heavy-metal emissions [13, 14, 15, 16,17].

Composting has been reported to excel over thermal, deposition, and other conventional methods of processing sludge with respect to fuel economy, nutrient recovery, and control of heavy-metal emissions [13, 14]. The treatment by composting leads to the development of microbial populations, which cause numerous physicochemical changes within the mixture. These changes could influence the metal distribution through release of heavy metals during organic matter mineralization or the metal solubilization by the decrease of pH, metal biosorption by the microbial biomass or metal complexation with the newly formed humic substances (HS) or other factors [6,7]. The objective of this work therefore is to assess the agronomic value of wastewater sludge compost through assessing its physicochemical and nutrients composition.

Materials and Methods

Sample Collection

Sludge sample was collected from Lower Usuma Dam Water Treatment Plant (LUDWTP), Bwari, Abuja, Nigeria. The Lower Usuma Water Treatment Plant is located within the Lower Usuma Water Works in Bwari Area Council at the periphery of Abuja Metropolis. It lies between the Latitude of $8^0$25 and $9^0$25 N and Longitude $6^0$45 and $7^0$45 E with an elevation of 2,000 meters above the sea level. The facility has capacity to process 120 million litres of waste water, delivery portable water to the city of Abuja and its environs. The facility has been in extensive use since 1987 and has in storage several tonnes of sludge.

Wood sawdust was collected from Uyo Local Government Area Timber Market in Akwa Ibom State, Nigeria using sagco black bags and then transfer to the laboratory for further treatment. The wood chips were air dried for 48h to a near constant weight before being used in the composting process.

Composting Procedure

Composting was carried out following the methods of Andreolli, Von-Sperling and Fernandes, [18]. The sludge was first decanted before measuring 35 kg and mixed with a bulking agent (sawdust) (47kg) in a vessel 0.8m high and 0.5m wide on a composting in-vessel type. The mixture was prepared so as to optimize the composting parameters. With the aim of maintaining aerobic conditions during the process, the compost was turned manually every 3 days.

Temperature was measured daily at a depth of 50 cm at different positions inside the vessel. The composting cycle lasted for 40 days and the compost was air-dried and bagged. Subsequently, Samples were taken systematically before composting (T_0), and after composting (T_{40}) for physicochemical, nutrients and metal content analysis, while samples were taken before composting (T_0), after 5 days of composting (T_5), and at T_{10}, T_{15}, T_{20}, $T_{25,}$ $T_{30,}$ T_{35} and T_{40} respectively for parameters like temperature and pH.

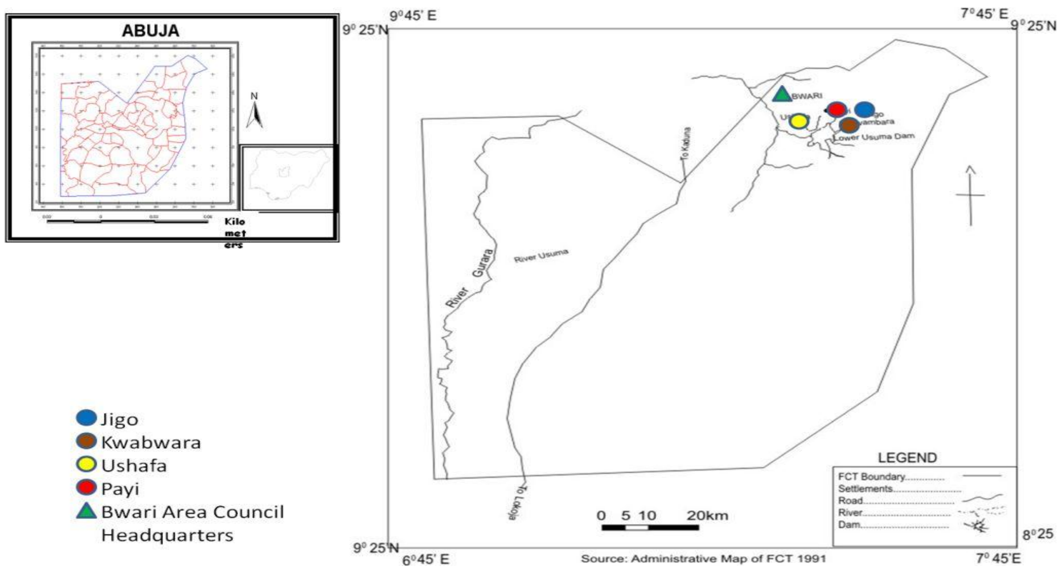

Figure 1: Delineated map of Abuja, Federal Capital Territory showing Lower Usuma Dam

Chemical Analysis of Resulting Composts

Sludge samples were taken from different points of compost heap (bottom, surface, side, and centre) at each stage of composting raw sludge mixture (0 day, sludge mixture after 40 day of composting). One aliquots of these representative samples was then used to perform physicochemical and nutrient analyses: pH and electrical conductivity were determined on a suspension of sample in water (10 g/15 ml), the total organic carbon (TOC) was measured according to the ANNE method [19], the total nitrogen (Kjeldahl method), inorganic nitrogen, the humic carbon extracted by 0.1 M NaOH solution was measured after oxidation by $KMnO_4$ [20]. Nutrient composition of raw sludge, composted sludge and wood sawdust were determined following standard protocols as described in details elsewhere [21- 26]. Total Ca, Na, K, Mg, Fe, Mn and trace metals (Cd, Zn, Cr, Co) were determined using Atomic Absorption Spectrophotometer (Unicam 939).

Results and Discussion

Physicochemical properties of raw sludge and wood sawdust

The physicochemical and nutrient properties of raw sludge and wood sawdust used in the composting are presented in Table 1. The raw sludge used in this study showed that it was low in C/N ratio (8.66) and high in nitrogen content (10.58).The phosphorus (phosphate) content of the sludge was 1.55mg/kg, while the potassium content was 4.12mg/kg. Some reported results proved that the potassium level in sludge is usually low and can range from 2.00 to 5.68mg/kg, but is enough for plant uptake and is still sufficient for crop requirement [27].

Apart from the plant nutrient, analysis of the sludge showed that it contained low amounts of trace elements especially chromium, cadmium, cobalt and copper, which will not have a negative impact on plant growth [28]. The presence of essential elements and trace metals in sludge from water treatment plants in Nigeria has previously been reported [29 -30]. Sources of these elements in sludge may be attributed to paint pigment used in the coating of the sludge tank as well as oils used in lubricating of the machine before and after production, from the plating and metal processing in the plant. High concentration of lead in waste water sludge may be attributed to emission from exhaust pipe of generating plants used to power machines during production according to report of Adelekan [31]. However the levels of trace elements in sludge studied from all locations were below the regulatory limit considered for the sludge samples

From the above results it appears that the sludge from LUDWTP water treatment plant was at an acceptable level for trace element and essential element (Table 1).

Table 1: Mean physicochemical Properties of Raw Sludge and Wood sawdust used in Composting

Parameters	Raw LUDWTP sludge	Sawdust
Physicochemical Properties		
pH	7.2±0.20	7.56±0.42
Total Organic Carbon (%)	6.89±0.42	2.14±0.12
Moisture Content (%)	24.57±1.93	30.05±1.55
Ash (%)	8.89±0.43	22.21±1.63
Electrical Conductivity (µs/Cm)	520±5.13	74±1.88
Organic matter (%)	91.7±0.00	69.95±2.06
C/N ratio	8.66	499.64
Nutrients		
Nitrogen (%)	10.58±1.26	0.14±0.01
Nitrate (mg/kg)	10.48±1.21	2.16 ±0.27
Sulphate (mg/kg)	8±1.01	0.89±0.12
Chloride (mg/kg)	0.14±0.00	0.20±0.00
Phosphate (mg/kg)	1.55±0.11	0.06±0.00
Ammonium ion (mg/kg)	2.2±0.20	0.19 ±0.04
Essential Elements		
Potassium (mg/kg)	4.12±0.42	0.07±0.01
Magnessium (mg/kg)	31.42±1.31	0.02±0.00
Calcium (mg/kg)	72.64±2.02	0.25±0.02
Manganese (mg/kg)	18.23±1.45	2.56±1.15
Sodium(mg/kg)	20.66±1.33	32.11±2.09
Iron (mg/kg)	58.15±0.12	18.34± 0.12
Trace Metals		
Chromium (mg/kg)	0.38±0.01	2.11±0.41
Zinc (mg/kg)	40.46±1.10	8.2±1.22
Copper (mg/kg)	0.45±0.00	0.81±0.01
Cadmium (mg/kg)	0.13±0.02	ND
Cobalt (mg/kg)	0.12±0.00	ND

LUDWTP – Lower Usuma Dam water treatment plant; ND – Not Detected

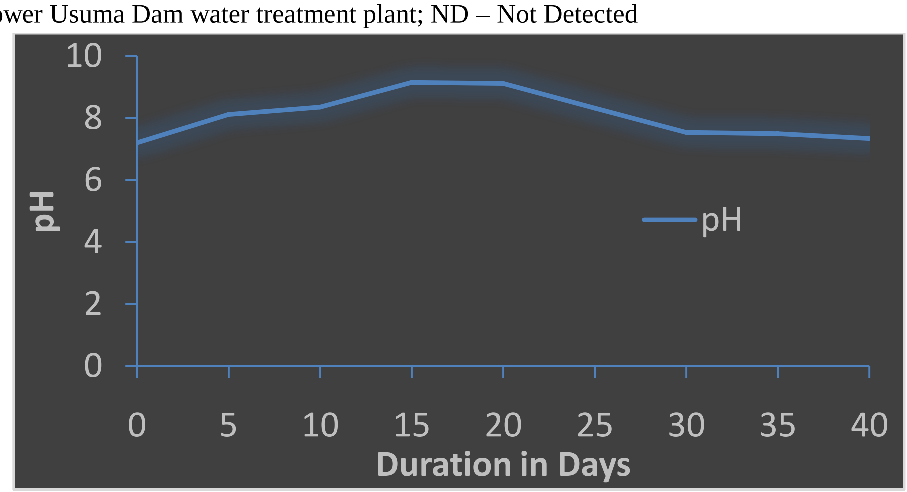

Figure 2: Changes in pH during composting

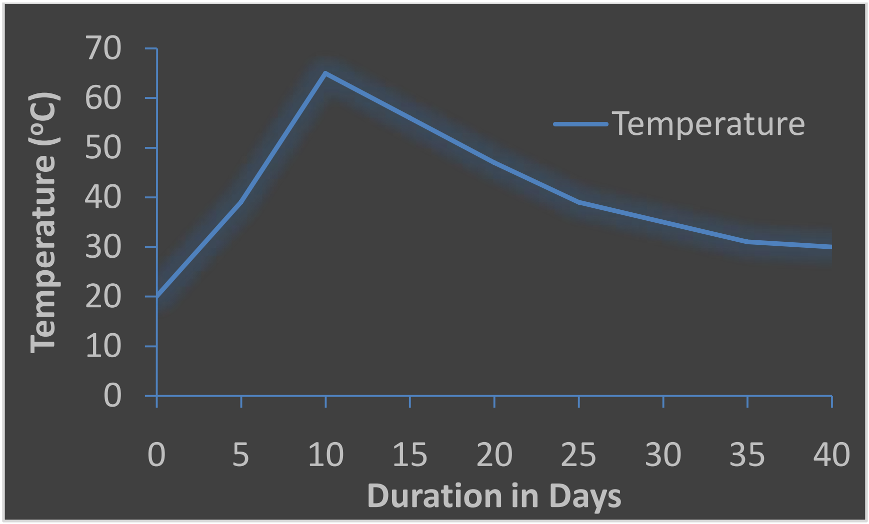

Figure 3: Changes in temperature during composting

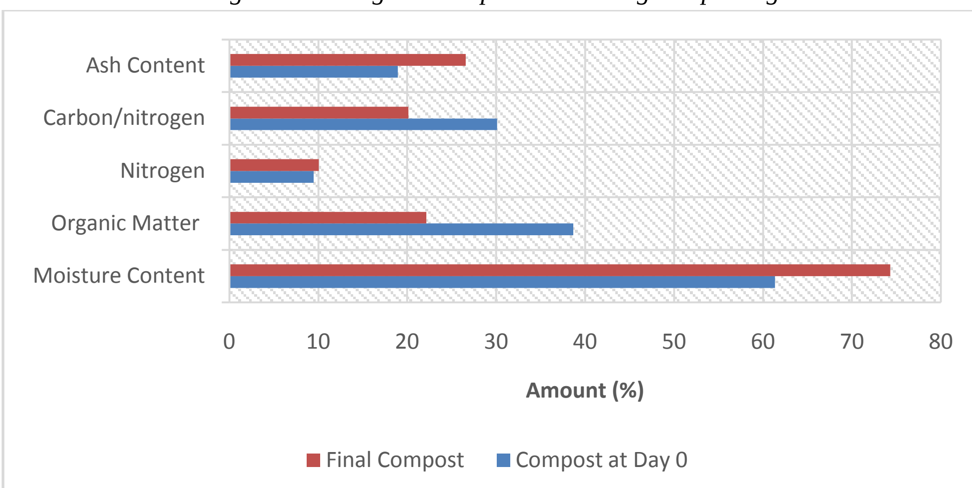

Figure 4: Physicochemical properties of compost after 40days

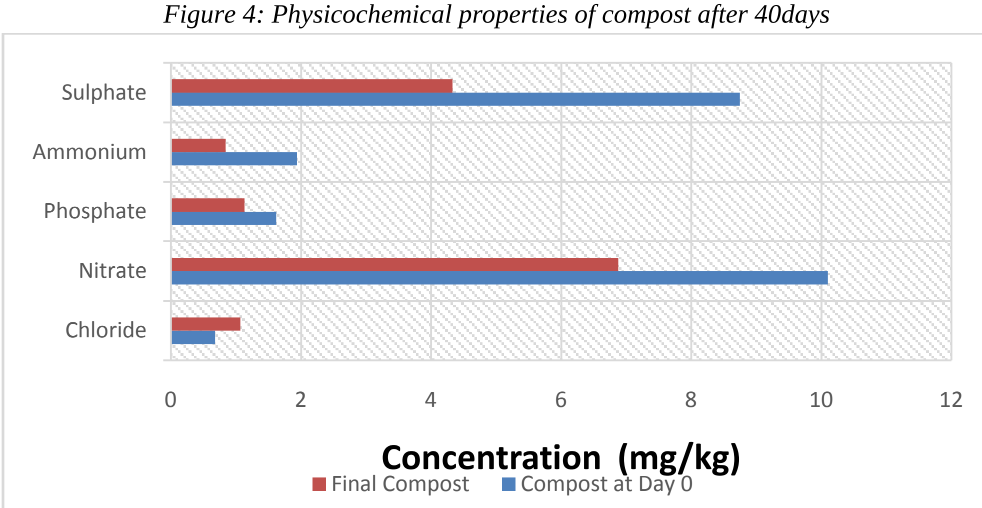

Figure 5: Nutrient profile of compost after 40days

Table 2: Essential and Trace elements composition of raw LUDWTP and Compost

	Raw LUDWTP	**COMPOST 40 DAY (Final day)**
Essential Elements		
Potassium (mg/kg)	4.12±0.42	2.89±0.13
Magnessium (mg/kg)	31.42±1.31	22.65±1.62
Calcium (mg/kg)	72.64±2.02	59.14± 4.33
Manganese (mg/kg)	18.23±1.45	15.17±1.66
Sodium(mg/kg)	20.66±1.33	14.32±0.89
Iron (mg/kg)	58.15±0.12	66.21±3.34
Trace Metals		
Chromium (mg/kg)	0.38±0.01	0.24±0.00
Zinc (mg/kg)	40.46±1.10	34.12±1.10
Copper (mg/kg)	0.45±0.00	0.13±0.07
Cadmium (mg/kg)	0.13±0.02	ND
Cobalt (mg/kg)	0.12±0.00	ND

LUDWTP – Lower Usuma Dam water treatment plant; ND – Not Detected

Characterization of compost

The changes in the physicochemical parameters and nutrient content of compost as revealed in this study could be attributed to the microbial growth dynamics ongoing during the process. The change in the C/N ratio from 8.66 to 2.21 and the increased in amount of ash from 8.89 – 26.56% reflect microbial decomposition of organic matter and stabilization during composting. Organic matter is decomposed and transformed to stable humic compounds which have a capacity to interact with metal ions, buffer pH, and act as a potential source of nutrients for plants. The increase in total nitrogen during composting was caused by the decrease of substrate carbon resulting from the loss of CO_2 (because of the decomposition of the organic matter which is chemically bound with Nitrogen) [32]. The decrease in the amount of inorganic nitrogen, N–NH_4 and N–NO_3 was as a result of the action of proteolytic bacteria and their partial incorporation into stable organic forms such as amide and heterocyclic nitrogen. Electrical conductivity of the final compost product did not exceed the salinity limit value of 3 ms/cm to be used as good fertilizers [33]. Available and total Phosphorous, Nitrogen, Sulpur, as well as Carbon make the compost good for use as a mineral fertilizer. Therefore, application of material will increase the stable organic Nitrogen and humic carbon and improve mineral elements necessary for plant growth. The aim of the composting experiment was to determine the effect of the composted material type and temperature fluctuations on the dynamics of changes taking place in the number of selected microbial groups in compost. During composting, microbial activities are diverse. Microbial population is often affected by exhaustion of nutrients; pH and temperature changes (figure 2 and 3). In the study, temperature was at its peak (65^{o}C, thermogenic phase) at day 10 of composting. Maintaining the temperature at 60^{o}C for the first 15days of composting may have caused a significant elimination of total aerobic heterotrophs, yeasts and moulds, *Salmonella* sp. and *Shigella* sp. At this temperature, only a few days are required to eliminate almost all pathogens [34]. Although aerobic bacteria (bacilli) are very often active between 60^{o}C and 65^{o}C, temperatures cannot exceed 75^{o}C, which would irreversibly denature the bacterial enzymes [35]. The intense microbial activity induced very significant transformations of the mixture of sewage sludge with saw dust used in composting. This assertion is further supported by Miyatake and Iwabuchi, [36] who noted that changes in temperature values during composting have an effect on changes in the activity and diversity of microorganisms, and thereby on composting efficiency

Trace Metal Content of Compost

Composting can concentrate or dilute heavy metals present in waste water sludge [7]. Lowering the amounts of heavy metal depends on metal loss through leaching. The increase of metal level is due to weight loss in the course of composting following organic matter decomposition, release of carbon dioxide and water and mineralization processes [37]. Table 2 also shows the total concentration of metals (Cr, Zn, Cu, Co, Cd) during composting. The order of total metal content in the final composted sludge was Zn > Cr > Cu while the levels of Cd and Co were not detected in the final compost. During composting, total trace metal content all decreased. This could be explained by metal loss through leaching in the course of composting. This loss mainly occurred during the thermophilic phase and could be related to metal release from decomposed organic matter, an increase of moisture from 24.57% to 74.32%, a change in other oxidizing and anionic conditions in the medium and therefore increasing the solubility of metals [7, 6, 33]. Some authors suggest that where the potential toxic metal concentrations of compost are high, the leachability of metal associated with compost is of concern [6]. The total trace metal content of compost after 40 days fell within the acceptable limit for different compost according to United State Environmental Protection Agency (table 3).

Table 3: Total trace metal contents in the final compost (40 Day) and Allowable limit for different class compost according to USEPA limit [38]

Trace metal	**Final compost (40 days) (mg/kg)**	**Allowable limit (mg/kg dry wt) Class A**	**Allowable limit (mg/kg dry wt) Class B**
Chromium	0.38	210	1060
Zinc	40.46	500	1850
Copper	0.45	100	757
Cadmium	0.13	3	20
Cobalt	0.12	20	85

Class A compost – No restriction in use; Class B compost – can be used on forest lands, roadsides and other landscaping purposes.

Conclusions

The study has revealed that throughout the 40 days of wastewater sludge composting, physicochemical properties of the compost reached relatively stable levels reflecting the stability and maturity of the final product, nitrogen content of raw did not vary significantly from that of the composted sludge. Phosphate, sulphate and chloride contents of composted sludge were infinitesimally higher than raw except for ammonium ion. The C/N ratio reaches the optimal range of stable compost; with total concentration of Cr, Zn, Cu, Co and Cd lowered in final compost supporting its use for agricultural purposes.

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