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RESEARCH ARTICLE

Contaminants in selected industrial effluents and their effect on groundwater quality near factories in two cities of South East Nigeria

Nwachukwu, O. I. [1], Odoemelam, L. E. [2],. and Muoneke, C. O.[3]

1. Department of Soil Science and Meteorology, Michael Okpara University of Agriculture, Umudike, Nigeria
2. Department of Rural Sociology and Extension, Michael Okpara University of Agriculture, Umudike, Nigeria
3. Department of Agronomy, Michael Okpara University of Agriculture, Umudike, Nigeria

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***Corresponding Author**

Nwachukwu, O. I

Abstract

Effluents from vegetable oil mill, paper mill and paint factories in Aba and Umuahia, South East Nigeria were analysed for contaminants and dissolved minerals. Water from boreholes within a 50m radius of the factories was also subjected to quality assessment. Paper and paint industry effluents contained the highest lead (21.6 mg/L), copper (27.5 mg/L), zinc (25.8 mg/L), cadmium (23.8 mg/L), chromium (31.7 mg/L) chloride (1600mg/L), and dissolved nitrate (43.9 mg/L) from vegetable oil mill were all above limits allowed for factory effluents. Fe levels in all three industrial effluents (0.6 – 6.4 mg/L) exceeded allowed limits. Water from boreholes in the vicinity of the three factories was acidic, with pH ranging from 4.8 – 5.6. Borehole water near the paint and paper factory had significantly elevated levels of dissolved nitrate (16. 83 and 22.3 mg/L respectively), above WHO limit allowed for drinking water in the long term. The discharge of paper mill effluents also led to elevated Cl (363 mg/L), Ca (113 mg/L), Mg (12 mg/L) and sulphate (349 mg/L) exceeding allowable limits in groundwater The heavy metal levels in all the boreholes analysed were however within safe limits.

INTRODUCTION

In the past two decades, industrial activities have been a major source of soil contamination in Nigeria (Oluwatosin et al., 2005; Pasquini, 2006). Large factories situated all over the country pose an environmental threat covering a wide area, as many industries in the country do not adhere to regulations for waste and effluent disposal (FEPA, 1991). Consequently, contamination of soil and groundwater from industries has been on the increase, and this has grave implications for human health (Okoronkwo et al., 2005)

The quality of groundwater is significantly influenced by surface water conditions and vice versa. Industries may cause atmospheric pollution which can lead to deposition of hazardous fallout to surface waters and to soils, and oftentimes, effluents and other wastes from factories may be deposited directly on land. These eventually percolate and may ultimately contaminate groundwater sources (Adebowale et. al., 2008). In general, shallow, permeable water table aquifers are the most susceptible to contamination, and the dilemma of groundwater pollution is that it is not easily detectable, with almost every instance of groundwater pollution being discovered only after a drinking water supply was affected.

Contaminants which can be found in polluted groundwater include dissolved nitrate and nitrite, pesticides, PAHs or heavy metals. The World Health Organisation has established limits on the quantity of heavy metals that can be present in drinking water, as high metal concentrations in drinking water has been linked to various diseases and even death (WHO, 1997). Nitrate is necessary for human and environmental health, and it is present in all tap and bottled waters, but high concentrations in drinking water can be harmful. The nitrate concentration in groundwater is normally low but can reach very high levels as a result of leaching or runoff from agricultural land together with contamination from human or animal wastes (Laftouhi et. al., 2003). It is produced during the natural decay of vegetable material in soil and the natural range in soil may be 0 – 100 mg/L (BGS, 2004). Usually, rainfall washes nitrate from sub-soil into groundwater.

In Nigeria, potable water through the public Water Board and water treatment plants is provided in only a few states, thus it is standard practice for homes, establishments and industries to provide their own water by sinking deep wells and boreholes (Ikem et. al., 2002). In some instances, the Local Governments may provide community boreholes. The quality of such groundwater is a direct indicator of the health of the ecosystem that makes up the natural drainage basin or watershed area, and monitoring it is vital to ensuring the integrity of a public water supply. The soil protection ordinance also requires that sites where a risk for groundwater quality is suspected must be evaluated with respect to the contaminant concentrations to be expected in the seepage water and shallow groundwater.

Given the proliferation of industries in Abia state, Nigeria, water from many boreholes is at risk of contamination because well water has been reported to be easily contaminated by dissolved contaminants (Pulford and Flowers, 2006). The risk is made worse by the fact that several industries are situated within residential areas, while the wastes from such factories are often discharged into the surrounding environment, invariably finding their way into groundwater sources (Nwachukwu et. al, 2010). This scenario becomes more alarming as borehole water is considered the safest source of drinking water inNigeria.

The focus of this research was to

i. evaluate the quality of groundwater in the vicinity of vegetable oil, paper and paint industries.

ii. determine the risks of metal contamination from industries in drinking water comparative to WHO guidelines

METHODOLOGY

The experiment was a 3x2x3 factorial in completely randomised design (CRD) with three industry types and two types of samples (i.e. factory effluent and borehole water), all having three replicates per type of sample. The factories studied were Vegetable oil factory, Umuahia; Paper Mill, Owerrinta and a paint factory at Aba, all in Abia State, Nigeria.

Sample collection

At the vegetable Factory, Umuahia, waste water and wastes were collected at the discharge points and trench of the vegetable oil factory into well labeled plastic bottles (Plate 1). All year round, this wastewater overflows from a sump situated a short distance from the factory into nearby farmlands. Groundwater was collected from two boreholes in the vicinity of the factory. It is worthy of note that one borehole had closed down due to oily substance continually present in the water.

At the Paper mill, Owerrinta, waste water was collected at the discharge point (Plate 2), and a trench carrying this was directly channeled to discharge into a river used by residents in the community for fishing, bathing and washing. Groundwater was collected from two boreholes within the premises of the factory. Photographs were not allowed at the paint factory, Aba, but wastes were collected from a heap at the discharge point, while water from two boreholes within the premises of the factory were sampled.

Wastes and wastewater from all factories were analysed extensively in the laboratory for pH, total content of nitrogen, phosphorus, exchangeable cations, heavy metals and quality such as biochemical oxygen demand (BOD), total dissolved solids and microbiological analyses.

RESULTS AND DISCUSSION

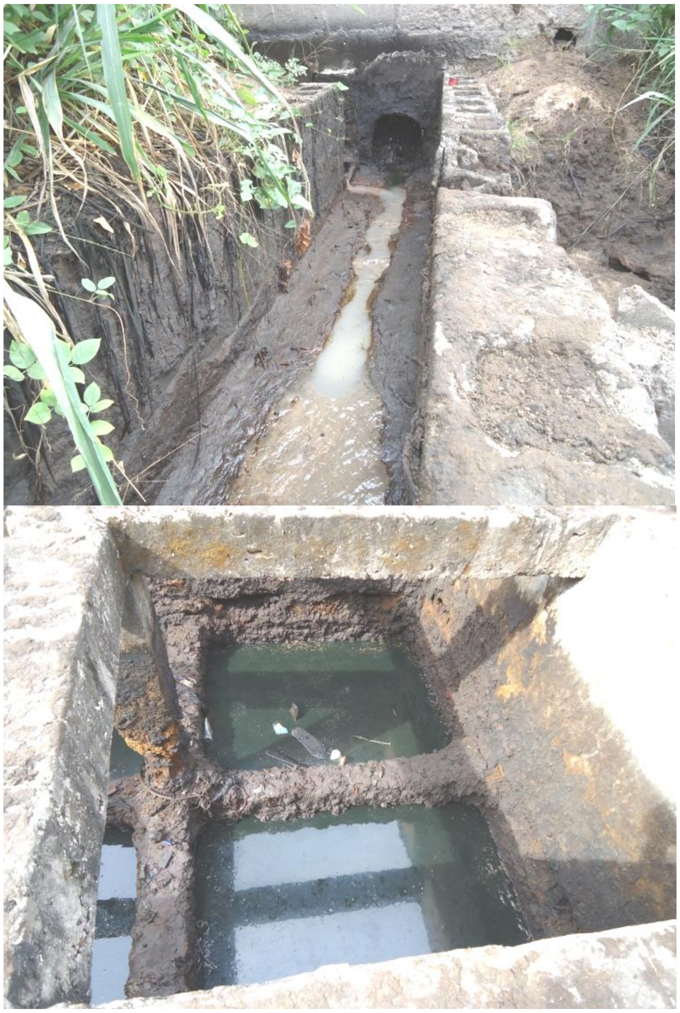

Plate 1. Waste water and sump at Vegetable Factory, Umuahia

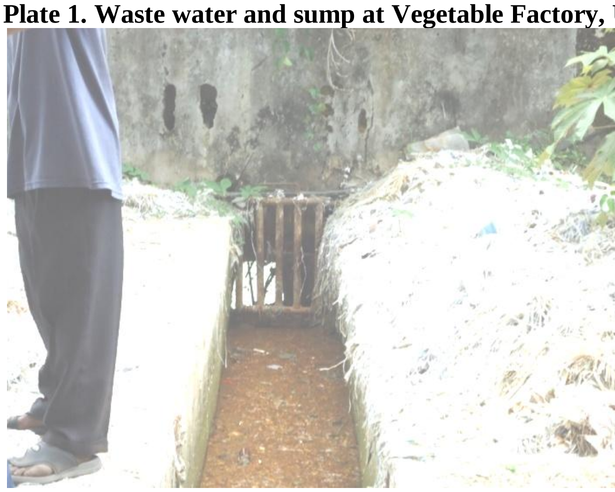

Plate 2. Treated paper mill wastewater discharged directly into a river

The pH of borehole water in the vicinity of all the industries evaluated was generally acidic, ranging between 4.93 and 5.57 (Table 1), whereas the overall pH range of natural water is between 6 and 8 (WHO, 1997). The pH of the effluents ranged from slightly acidic to slightly basic (Table 1), and they have effect on pH value of receiving groundwater. Water with pH below 4 will taste sour, while that with pH above 8.5 gives a bitter taste (WHO, 1997).

In addition, higher pH value of drinking water can hasten scale formation in water heating apparatus and reduce the germicidal potential of chlorine. On the other hand, pH below 6.5 starts corrosion in pipes, thereby releasing toxic metals such as Zn, Pb, Cd, Cu etc (BGS, 2004).

Table 1. Quality assessment of Industrial effluents from Vegetable Oil, paper mill and paint industries

Quality	Vegetable Oil factory	Paper mill	Paint industry	Limit (NIS)
Appearance	Cloudy	Whitish	Clear	Clear/colourless
Odour	Objectionable	Objectionable	Unobjectionable	Unobjectionable
Taste	NA	NA	NA	Tasteless
Turbidity (ntu)	10	12	12	5
Colour (tcu)	5.5	5.8	1.0	3
pH at 25°	6.04	8.74	7.44	6.6 – 8.5
Suspended matter/particles	Present	Present	Nil	Nil
Free carbon(IV) oxide (mg/l)	-	-	-	10
Total dissolved solids (TDS) mg/l	163	2140	196	500
Conductivity (mmhos/cm)	312	2583	799	1000
Dissolved Oxygen	8.94	4.8	7.18	-
Biochemical oxygen demand (BOD)	21.10	296	5.66	-
Total hardness (mg/l)	60.00	149	1020	100
Phenols	-	-	-	0.05
Pesticides (mg/l)	0.01	NA	NA	0.003

NA- not applicable

The effluents from the two factories were also analysed for the presence heavy metals, cations and other chemical compounds, and the results are presented in Table 2. Iron (2.4 mg/L), copper (5.0 mg/L), zinc (6.0 mg/L), chloride (1600mg/L) and dissolved nitrate (43.9 mg/L) in effluents were all above allowable limits (Table 2).

Table 2. Heavy metal levels and selected compounds in industrial effluents

Heavy metal /cation chemical cmpd (mg/l)	Vegetable Oil Factory	Paper Mill	Paint Industry	Limit (NIS)
Lead	bdl	21.6	0.01	0.01
Aluminium	Bdl	Bdl	Bdl	-
Iron	2.37	6.4	0.64	0.3
Copper	0.087	27.5	5.00	1.00
Zinc	Bdl	25.8	6.00	5.00
Mercury	0.00	0.00	0.00	na

Cadmium	Bdl	23.8	Bdl	0.01
Chromium	Bdl	31.7	Bdl	0.05
Chloride	100	587	1600	100
Calcium	29.94	521	500	75
Magnesium	10.24	14.3	3.04	2.0
Sulphate	4.00	709	2100	100
Nitrate	43.86	40.5	7.00	10
Nitrite	0.04	0.07	15.00	0.01
Phosphate	2.75	1.32	540	-
Phenols	Bdl	Bdl	Bdl	-
Cyanide	0.01	0.00	0.00	0.01

Bdl- below detectable limits

Water quality of boreholes in the area is shown in Table 3, and the water colour, hardness, and pesticide levels were within acceptable limits (WHO, 1997).

Table 3. Quality assessment of borehole water from the vicinity of Vegetable Oil, Paper Mill and Paint industries

Parameter	Vegetable Oil Factory	Paper Mill	Paint Industry	Allowable limit
Appearance	Clear/colourless	Clear/colourless	Clear	Clear/colourless
Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
Taste	NA	NA	NA	Tasteless
Turbidity (ntu)	2.0	2.0	2.0	5
Colour (tcu)	1.0	1.0	1.0	3
pH at 25°	4.93	5.57	4.79	6.6 – 8.5
Suspended matter/particles	Nil	Nil	Nil	Nil
Free carbon(IV) oxide (mg/l)	-	-	10	10
Total dissolved solids (TDS) mg/l	49	4	500	500
Conductivity (mmhos/cm)	102	1583	1000	1000
Dissolved Oxygen	9.19	9.22	8.69	-
Biochemical oxygen demand (BOD)	1.65	1.85	2.16	-
Total hardness (mg/l)	18.00	149	17	100

Phenols	bdl	bdl	bdl	0.05
Pesticides (mg/l)	0.00	0.00	0.00	0.003

Heavy metal, nitrate and nitrite content of borehole water are shown in Table 4.
Heavy metal levels in borehole water from the vicinity of all three factories were generally within acceptable limits (Table 4).

Table 4. Heavy metal levels and selected compounds in borehole water from the vicinity of factories

Heavy metal / cation/ chemical compound (mg/l)	**Vegetable Oil Factory**	**Paper mill**	**Paint Industry**	**Allowable limit**
Lead	0.00	0.00	0.00	0.01
Aluminium	0.00	0.00	0.00	na
Iron	0.05	0.036	0.023	0.3
Copper	0.04	0.00	0.01	1.00
Zinc	0.00	0.00	0.02	5.00
Mercury	0.00	0.00	0.00	na
Cadmium	0.00	0.00	0.00	na
Barium	0.00	0.00	0.00	1.00
Chloride	17.00	363	15	100
Calcium	15.24	113	15.21	75
Magnesium	0.18	12.00	0.02	2.0
Sulphate	0.00	349	4.42	100
Nitrate	16.83	22.30	6.72	10
Nitrite	0.00	0.00	0.00	0.01
Phosphate	0.77	0.50	25	-
Phenols	-	-	-	-
Cyanide	0.00	0.00	0.00	0.01

Bdl- below detectable limits

Though non toxic, metal levels were higher than that found in boreholes which are not situated near factories (Abii and Nwabienvanne, 2007). Khan (2001) also reported that groundwater in areas near to source of factory effluent discharge was contaminated as compared to areas away from the source. The non toxic levels of metals found in borehole water may be due to greater run off rather than percolation of contaminants into the boreholes ampled, being near the factory, which were generally at high elevations with a distinct slope. The peculiar nature of soils at each site may also have a direct effect, as it has been shown that occurrence of trace elements in groundwater is directly related to soil characteristics that determine the rate of water movement within the soil (Ilyas and Sarwar, 2003). This scenario may change with longer and continued exposure to industrial effluents. Nevertheless, chloride in boreholes near the paint factory significantly exceeded the levels allowed for drinking water, and this high content would be due to the process of repeated bleaching which takes place during the manufacture of paper (Senthilkumar, et. al., 2011).

Nitrate in borehole water from the vicinity of vegetable oil factory and paper mill was 16.83mg/L and 22.3 mg/L respectively (Table 4), far above the 10mg/L allowed limit for safe drinking water (WHO, 1997, 1998). It is desired that nitrate be less than 10ppm in safe drinking water for the long term (Shrestha and Ladha, 2002), although WHO limit for short term exposure allows up to 50mg/L (WHO, 1997, 1998). This standard is intended to ensure that drinking water will not cause methaemoglobinaemia. Nitrogenous fertilisers used on arable farmland can be a significant source of nitrate in groundwater and surface water and this may account for elevated nitrate found in boreholes near the vegetable oil factory, where effluent runoff actually passed through farmlands in the vicinity.

CONCLUSIONS

The industries evaluated were found to have introduced toxic substances into the groundwater in their environs, causing borehole water in the vicinity of vegetable oil, paper mill and paint industries to have elevated levels of heavy metals, even where such levels were still within acceptable limits for drinking water. Thus drinking water in the vicinity of the three factories could become potentially unsafe if there is continued impact by industrial effluents. It was established that activities of the vegetable oil factory led to the closing down of a community borehole due to the presence of factory contaminants in the water. This is alarming, and it is required that waste disposal laws be strictly enforced to prevent further occurrence. Maintaining high water quality is essential to ensure the integrity of a public water supply, and the impact of the industries on groundwater in this study indicates a potential for harmful effects to human health.

It is recommended that appropriate waste treatment and disposal practices be enforced by the regulatory agencies, in order to prevent water contamination in Abia State. In addition, the location of industries should be prohibited in residential areas. Finally, additional preventative measures should be taken to avoid elevated nitrate in water, such as having a proper knowledge of previous and ongoing land use practices, while particular attention should be paid to the area up-gradient in order to determine direction of groundwater flow toward wells/boreholes.

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