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The analysis of physicochemical characteristics of pig farm seepage and its possible impact on the receiving natural environment

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Pig farm seepage poses an environmental risk, considering that seepage can be generally applied on land without appropriate agronomic criteria or may accidentally spill on the natural environment. These environmental risks include increasing oxygen demand, nutrient loading of water-bodies, promoting toxic and algal blooms eutrophication, thus, leading to a destabilized environment. This research was conducted to determine the impact that the pig farm seepage may have the receiving environment based on the analyses of the physicochemical parameters of the adjacent environments. Wastewater and soil samples were collected between the periods of March 2013 to August 2013 and wastewater was analyzed for pH, temperature, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), salinity, turbidity, Dissolved Oxygen (DO), NO_3, NO_2, and PO_4^{3-}. The results for wastewater samples for BOD (163 mg/L to 3350 mg/L), TDS (0.77 g/L to 6.48 mg/L), COD (210 mg/L to 9400 mg/L), and NO_3 (55 mg/L to 1680 mg/L), were higher than the maximum permissible limits. Results of soil samples for TDS (0.01g/L to 0.88 g/L), COD (40 mg/L to 304 mg/L), NO_3 (32.5 mg/L to 475 mg/L), and NO_2 (7.35 mg/L to 255 mg/L) were also higher than recommended limits. The results revealed that the seepage from pig farm degraded the natural environment by causing eutrophication, promote toxic and algal blooms, increase oxygen demand and thus destabilize the homeostatic balance of the receiving environment.

Key words: Physicochemical parameters, pollution, soil, wastewater, seepage, pig farm, environment.

INTRODUCTION

Agricultural activities in South Africa are advancing and increasing at an alarming rate and this may overburden the environment with organic substances from seepage mainly livestock droppings, heavy metals, fertilizers and

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pesticides (Muhibbu-din et al., 2011). Mismanagement of seepage may pollute the environment with nitrogen, phosphorus, bacteriological pathogens, and parasites, which may impact negatively on the environment (Ramı´rez et al., 2005). Pollution is caused when a change in the physical, chemical, or biological condition in the environment harmfully affects the quality of the environment.

Pollution of the environment can have serious consequences, with negative impact on the aquatic life, from microorganisms to insects, birds, fish, and at the same time, the health of terrestrial animals and plants (Pachepsky et al., 2006). Land application of seepage may expose the receiving environment to pollutants, and it might become hazard and even toxic to the receiving environment (Obasi et al., 2008). Mass storage production of seepage of pig farm wastewater may also be a serious hazard for biological balance of the environment (Pachepsky et al., 2006). Most pig farms, store their seepage in lagoons for a long time and this may cause pollutants to leach through the soil and pollute ground water (Pachepsky et al., 2006).

Pig farms, also known as feedlots that house thousands of pigs, produce staggering amounts of animal seepage (Tymczyna et al., 2000). The way this seepage is stored in lagoons and used has profound effects on the natural environment (González et al., 2009). These cesspools often break, leak or overflow, sending dangerous microbes, nitrate pollution, organic and inorganic pollutants into the environment (Rufete et al., 2006). Environmental contamination by pig farm seepage can be associated with heavy disease burden and the assessment of disposal and management of this seepage is very important to safeguard the environment from pollution (Okoh et al., 2007). Monitoring the physicochemical parameters of soil and water systems is important to safely assess the environment for contamination (Singh et al., 2012). High seepage discharge or spillage is a major component of water pollution contributing to oxygen demand, nutrient loading, toxicity, eutrophication and algal blooms that destabilize the environment (González et al., 2009).

The physicochemical parameters of the receiving environment that may be affected by seepage includes pH, temperature, Electrical Conductivity (EC), salinity, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand (COD), concentrations of nitrate (NO_3), nitrite (NO_2), and orthophosphate (PO_4^{3}) (Muhibbu-din et al., 2011). Surrounding environments in the vicinity of pig farms may be contaminated due to fecal residues, seepage runoff and mismanagement of pig farm seepage. Thus, this may cause a threat to rivers, lakes and land surrounding the pig farms, with a significantly high contamination potential for groundwater (Villamar et al., 2011). The aim of this study is to assess the possible impacts of pig farm seepage on the natural environment by monitoring the physicochemical parameters of the seepage.

METHODOLOGY

Study area

The project was conducted at the Agricultural Research Council (Animal Production Institute). The ARC-Irene Campus is situated about 25 km south of Pretoria (25° 52′S, 28° 13′E/25.867°S 28.217°E/-25.867; 28.217) in Gauteng. The institution houses a dairy farm, pig farm, sheep farm and chicken farm.

Sampling

Wastewater samples and top soil (30 cm deep) samples were collected at the ARC-API pig farm. These samples were collected monthly from March to August 2013 between 07h00 and 09h00 A.m., on weekly basis. These samples were collected to determine their physicochemical parameters namely BOD, COD, Salinity, pH, Temperature, EC, TDS, Turbidity, DO, concentrations of NO_3, NO_2, and PO_4^{3-}.

Wastewater samples (1 L) were collected in triplicates in 1 L glass bottles cleaned with dilute nitric acid (HNO_3) and detergent, then followed by deionized water (Igbinosa and Okoh, 2009; Standard Methods, 2001). Wastewater samples were collected from 4 sites at the pig farm that is Pig farm enclosures (Enc W), pig farm influent 2 m from the constructed wetland (Influent), constructed wetland for wastewater treatment (CW), and final effluent 2 m from the constructed wetland (effluent). Before sampling from each site, sampling glass bottles were flushed three times before being filled with the sample. Sampling of wastewater was done by dipping each sample bottle at approximately 20-30 cm below surface, projecting the mouth of the container against the flow direction (Igbinosa and Okoh, 2009).

Soil samples about 2 kg were collected using soil auger in sterile polythene bags at depth of 30 cm (Bhat et al., 2011). Soil samples were collected from 5 sites at pig farm that is, pig farm enclosures (Enc S), soil 20 m (Enc S-20 m) and 100 m (Enc S-100 m) away from the pig farm enclosures, soil 20 m (CW S-20 m) and 100 m (CW S-100 m) from pig farm constructed wetland. Wastewater and soil samples were placed on ice in a cooler box immediately after sampling and transported to the lab to be analyzed.

Critical parameters such as BOD, Salinity, pH, Temperature, EC, TDS, Turbidity, DO, concentrations of NO_3, NO_2, and PO_4^{3-}, were tested on the same day of sampling while the COD parameter was tested within its time limit. Samples for analyses of COD were collected separately in 1 L bottles and preserved with 0.2 mL of concentrated sulphuric acid on point of sampling and were analyzed within 28 days.

Physicochemical analysis

Parameters such as pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), salinity, dissolved oxygen (DO), turbidity and biological oxygen demand (BOD) for water samples were determined onsite using a multi-parameter ion specific meter (Hanna instruments, version HI9828). Analysis of each parameter for wastewater was performed in triplicates. Blank samples (deionized water) were passed between every three measurements of samples to check for any eventual contamination or abnormal response of equipment. Temperature and pH were measured for both water and soil samples (Singh et al., 2012).

First analyses of BOD and DO were performed onsite, then again in the laboratory. BOD and DO were measured using BOD LDO Probe (Model LBOD 10101). The BOD and DO determination of the wastewater samples was carried out using standard methods described by APHA (1998). A 300 ml BOD bottle was used to add 297 ml of BOD nutrient pillow and 3 ml of sample. The results for BOD were recorded when the BOD LDO probe had stabilized. The dissolved oxygen (BOD) content was determined before and after incubation. Sample incubation for BOD was for five days in the dark at 20°C in BOD bottle. The following formula was used to calculate BOD_5:

$$BOD_5 = (D_1 - D_2)/P$$

Where:
BOD_5 = BOD value from the five day test
D_1 = DO of diluted sample immediately after preparation
D_2 = DO of diluted sample after five days incubation at 20 ± 1°C, in mg/L
P = Decimal volumetric fraction of sample used.

For measuring DO in samples, 300 ml of sample was poured into 300 ml BOD bottles (Singh et al., 2012). The results for DO were recorded when the probe had stabilized.

Analyses of TDS, EC NO_3, NO_2, PO_4^{3-}, and salinity were also adopted from Singh et al. (2012) (with amendments) and Standard Methods (2001) were followed in determining the aforementioned variables. Salinity, TDS, and EC were measured using HACH CDC401 probe. About 250 ml of the sample was poured into a 300 mL beaker, the HACH CDC401 probe was placed in the sample and the results were taken in triplicates. The probe was rinsed in deionized water after each test.

Concentrations of NO_3, NO_2, PO_4^{3-}, and COD were read using spectrophotometer HACH DR 500. Blank determinations were performed for COD, PO_4^{3-}, NO_3, and NO_2. PO_4^{3-} and was determined using the Molybdovanadate method (HACH Method 8114) (HACH, 2008). PO_4^{3-} was measured by adding 20 ml of the sample into a 25 ml graduated mixing cylinder. 1 content of Molybdate, 1 Reagent Powder Pillow was added to sample. The cylinder was stoppered and shaken to dissolve reagents. Then 10 ml of prepared samples was added to a 10 mL square sample cell and 0.5 mL of molybdenum, 2 Reagent was added and the cell was swirled and left to stand for 2 min for reaction to complete and results were taken immediately upon completion.

NO_3 was analyzed using the cadmium reduction method (HACH Method 8039) (HACH, 2008). Nitrate was then measured by adding 10 ml of sample into a 10 mL square sample cell and NitraVer 5 Nitrate Reagent powder pillow (HACH) was added to the sample. The reaction was left standing for 1 min and then shaken vigorously and left for another 5 min for the reaction to complete. The results were read immediately.

NO_2 was analyzed using the ferrous sulphate method (HACH Method 8153) (HACH, 2008). Nitrite was measured by adding 10 mL of sample into a 10 mL square sample cell and 1 content of NitriVer 2 Nitrite Reagent Powder pillow (HACH). The cell was stoppered and shaken to dissolve the contents. When completely dissolved, the solution was left to stand for 10 min for the reaction to complete and the results were taken immediately.

Standard Methods (2001) was followed for analyses of COD, where 100 ml of sample was homogenized in a blender for 30 s and 250 ml of sample was poured into a beaker and gently stirred on a magnetic stir plate. About 2 mL of the homogenized sample was pipette from the beaker into a vial containing potassium dichromate. The vial was inverted several times and then placed into a 150°C preheated DRB200 reactor for 2 h. Results were read when vials were completely cooled.

Turbidity was measured using DR5000 spectrophotometer. About 1.5 ml of sample was pipetted into 2 mL cuvettes and placed in the DR 5000 spectrophotometer 1-inch cell adapter (Singh et al., 2012). The results were read at 860 nm wavelength.

For soil samples, 100 g of air dried soil sample (air dried at 65°C) was mixed with 1 L of deionized water in a 1 L bottle previously cleaned with dilute Nitric acid (HNO_3) and detergent, then followed by deionized water (Bhat et al., 2011). This soil solution was mixed for 5 h using a magnetic stir plate. The solution was then removed and placed on the bench and left for 30 min for the soil to settle completely at the bottom (Bhat et al., 2011). Soil samples were analyzed for pH, temperature, salinity, EC, DO, TDS, COD, PO_4^{3-}, NO_3, and NO_2. Similar procedure for analyzing the physicochemical parameter for water was also adopted for analyzing physicochemical parameters of soil.

Statistical analysis

Calculation of means and standard deviations were performed using Microsoft Excel office 2010 version. Correlations (paired T-test) and test of significance (two-way ANOVA) were performed using SPSS 17.0 version for Windows program (SPSS, Inc.). All tests of significance and correlations were considered statistically significant at P values of < 0.05.

RESULTS

Mean and standard deviation (SD) values for each of the physicochemical parameter analyses were done in triplicates of wastewater. Samples are given in Table 1, and sample for soil is given in Table 3. Their P-value and F-value along with their significance are given in Table 2 for wastewater samples and in Table 4 for soil samples.

The results for physicochemical parameters of wastewater samples (Table 1) ranged from 6.5 to 9 (pH), 1.25 mS/cm to 5.58 mS/cm (EC), 8 to 28°C (temperature), 163 to 3550 mg/L (BOD), 0.77 to 6.48 g/L (TDS). Table 1 also shows results for salinity, COD, turbidity, and DO for wastewater samples ranged from 0.83 to 6.35 psu, 210 to 9400 mg/L, 0.21 to 3.65 NTU and 4.14 to 7.64 mg/L, respectively. Concentrations of PO_4^{3-}, NO_3, and NO_2 for wastewater samples (Table 1) ranged from 55 to 1680 mg/L, 37.5 to 2730 mg/L and 50 to 1427 mg/L, respectively. Results for pH, BOD, COD, DO, salinity, temperature, nitrate, nitrite, orthophosphate varied significantly ($p<0.05$) and results variation for EC, TDS, turbidity were insignificant (Table 2).

Physicochemical parameters analyzed for soil samples were, pH, temperature, salinity, EC, DO, COD, TDS, and the concentrations of PO_4^{3-}, NO_3, and NO_2. Table 3 shows that results for the physiochemical parameters of soil samples ranged from 6.28 to 8.43 (pH), 0.11 mS/cm to 1.37 mS/cm (EC), 12 to 25.5°C (temperature). Results for TDS, salinity, COD, and DO (Table 3) for soil samples ranged from 0.01 to 0.88 g/L, 0.01 to 0.13 psu, 40 to 304 mg/L, and 5.31 to 8.45 mg/L, respectively. Results for the concentration of PO_4^{3-}, NO_3, and NO_2 (Table 3) also

Table 1. Physicochemical parameters of wastewater for pig farm.

Sampling period	Sampling point	parameters											
		pH	Temp. (°C)	Salinity (psu)	EC (mS/cm)	BOD (mg/L)	TDS (g/L)	Turbidity (NTU)	COD (mg/L)	DO (mg/L)	PO_4^{3-}(mg/L)	NO_2 (mg/L)	NO_3 (mg/L)
March	Enc W	7.25±0.5	22.4±0.95	1.18±0.07	3.10±0.13	413.54±15.94	6.19±0.17	1.23±0.13	3122.8±22	7.35±0.66	246.89±7.60	308.78±12	430.51±6.6
	Influent	9±0.00	25±0.00	2.08±0.06	3.50±003	694.5±31.25	6.48±0.10	1.79±0.31	4050±78.25	5.18±0.09	324.5±0.45	498.5±0.05	517.50±2.3
	CW	8.5±0.71	28±1.41	0.99±0.06	2.11±0.31	289.2±95.05	6.10±0.23	1.01±0.20	1025.3±704	6.14±0.93	331.04±40	209.13±93	438.1±232
	Effluent	8±0.00	26±0.00	1.08±0.01	1.58±0.04	163±5.23	4.07±0.01	0.41±0.11	521±13.50	6.51±0.25	55.9±0.35	75±0.13	550±0.31
April	Enc W	7.5±0.8	15.8±1.05	2.90±0.49	2.64±0.19	767.25±5.91	2.28±0.48	2.57±0.20	5087.5±246	7.64±0.09	825.13±53	66.88±7.12	146±27.53
	Influent	8±0.00	20±0.00	3.74±0.10	4.17±0.05	770±49.35	3.66±0.11	3.10±0.71	9400±99.1	5.64±0.47	980.5±0.4	202.5±1.1	625±3.41
	CW	8.±0.00	19.5±0.71	1.21±0.27	2.02±0.39	645.5±160.5	1.16±0.02	1.41±0.45	843±357.80	7.25±0.70	833.96±42.2	109.9±55.3	169.5±85.6
	Effluent	8±0.00	18±0.00	0.83±0.04	1.25±0.06	623±11.31	1.03±0.04	0.58±0.52	512±96.07	6.19±0.05	992.32±0.08	52±0.71	70.83±0.72
May	Enc W	8.25±0.5	8.75±1.5	4.58±0.58	3.49±0.35	1247.95±292	3.73±1.14	2.43±0.17	6545±456.9	5.94±0.52	893.88±69.9	169.75±13	1306±134
	Influent	8±0.00	15±0.00	6.35±0.16	5.58±0.13	2562.5±25	6.32±0.26	2.85±0.27	7065±87	5.23±0.11	1427±0.2	233.5±0.4	1407±48.4
	CW	8±0.00	18±1.41	3.42±1.76	2.75±0.63	1758.95±320	3.91±1.05	1.93±0.74	3288±1403	5.39±0.20	1170.5±112.4	170.5±112	464.3±89.4
	Effluent	8±0.00	18±0.00	1.13±0.05	2.24±0.08	1263.2±83	2.12±0.05	0.41±0.36	760±99.6	5,43±0.02	853.19±0.1	37.5±1.37	637.5±2.0
June	Enc W	7.5±0.58	9.0±4.08	1.42±0.16	2.72±0.28	2168.5±244.3	1.61±0.29	2.26±0.18	5832.5±541	5.87±0.79	829±44.80	1425±132	471.3±22.9
	Influent	8±0.00	14±0.00	2.04±0.07	3.04±0.07	3350±209	2.03±0.05	2.60±0.39	7500±74.	4.14±0.05	925±0.28	2458±1.0	693±0.99
	CW	8±0.00	14±1.41	1.04±0.18	2.03±0.34	1745±625.80	1.02±0.17	1.33±0.34	6210±622.3	4.54±0.11	373.16±229	1131±149	325±176.8
	Effluent	8±0.00	15±0.00	0.93±0.07	2.24±0.04	1010±99.0	0.77±0.06	0.74±0.29	4560±94	4.87±0.08	99.31±0.3	653±0.17	145±0.93
July	Enc W	7.75±0.5	8.13±1.65	1.66±0.37	3.23±0.61	2066.38±607	1.67±0.33	2.26±0.25	6464±373.9	5.22±0.31	175.75±14	1625±64.5	581.3±41.5
	Influent	8±0.00	12,5±0.00	3.64±0.09	4.29±0.02	3152±68.3	2.64±0.09	3.65±0.46	7295±89.9	4.71±0.06	235±0.31	2730±1.21	1680±1.80
	CW	7.5±0.71	13.25±2.48	1.06±0.18	2.07±0.34	1020±38.89	1.05±0.18	1.01±0.57	1792.5±894	5.05±0.55	170±21.21	1125±460	1060±283
	Effluent	7±0.00	13±0.00	0.84±0.06	1.67±0.04	402.5±34.5	0.83±0.04	0.21±0.19	940±79.83	5.80±0.08	125±0.32	350±0.07	530±0.61
August	Enc W	7.5±0.58	8.0 ±0.82	1.46±0.43	2.20±0.82	1583.63±317	1.53±0.33	1.49±0.17	1718.5±132	5.73±0.45	173.75±14.9	1173.5±33.	178.8±11.8
	Influent	6±0.00	11±0.00	2.64±0.13	4.01±0.06	3550±480.8	3.35±0.06	2.24±0.51	3580±90.91	4.46±0.21	240±0.27	1850±0.86	490±1.31
	CW	8±0.00	11.5±1.41	1.15±0.15	2.54±0.71	1405±134.35	1.13±0.14	0.92±0.25	1100±608.1	4.97±0.35	107.5±38.89	425±35.36	105±35.36
	Effluent	8±0.00	16±0.00	0.93±0.07	1.84±0.06	1170±10.61	0.93±0.01	0.52±0.22	210±127.28	4.75±0,08	50±0.10	250±0.01	55±0.20
Standards Error		6-9	<25	33-35	70	<40	450	<5	≤1000	≥5	≤30	≤0.5	≤20

Temp: Temperature; EC: Electrical Conductivity; BOD: Biological Oxygen Demand; TDS: Total Dissolved Solids; COD: Chemical Oxygen Demand; DO: Dissolved Solids; PO_4^{3-}: Orthophosphate; NO_2: Nitrite; NO_3: Nitrate. The table shows results for physicochemical parameters of pig farm wastewater samples where the standards were adopted from DWARF (1996).

Table 2. The P-value and F-value for physicochemical parameters of wastewater for pig farm.

P and F values	Parameters											
	pH	Temp.	Salinity	EC	BOD	TDS	Turbidity	COD	DO	Ortho-P	NO_2	NO_3
F values[a]	2.91	71.59	32.21	1.01	28.62	0.86	0.74	3.79	32.58	13.95	39.53	7.22
P values[b]	0.02*	0.00*	0.00*	0.42	0.00*	0.51	0.60	0.00*	0.00*	0.00*	0.00*	0.00*
F values[c]	6.07	4.75	7.85	1.01	7.23	1.21	1.25	2.45	6.37	9.90	4.99	2.08
P values[d]	0.00*	0.00*	0.00*	0.43	0.00*	0.30	0.28	0.02*	0.00*	0.00*	0.00*	0.05*
F values[e]	3.55	10.22	11.52	0.93	10.28	0.98	0.98	2.87	4.95	9.14	12.58	4.00
P values[f]	0.00*	0.00*	0.00*	0.52	0.00*	0.47	0.47	0.00*	0.00*	0.00*	0.00*	0.00*

Temp: Temperature; EC: Electrical Conductivity; BOD: Biological Oxygen Demand; TDS: Total Dissolved Solids; COD: Chemical Oxygen Demand; DO: Dissolved Solids; Ortho-P: Orthophosphate; NO_2: Nitrite; NO_3: Nitrate. *P<0.05 significant variation. Values are expressed in milligrams per litre except in pH, temperature (in degrees Celsius), salinity (in practical salinity unit), and EC (in micro-Siemens per centimetre), TDS (grams per litre). [a]F values for parameters and month. [b]P values for parameters and month. [c]F values for parameters and sampling point. [d]P values for parameter and sampling point. [e]F values for combined effect of month and sampling point on parameters. [f]P values for combined effect of month and sampling point on parameter.

ranged from 32.5 to 475 mg/L, 9 to 142 mg/L and 7.35 to 255 mg/L. All the results for the physicochemical parameters of soil samples varied significantly (p<0.05), monthly (Table 4).

The correlation of the physicochemical parameter of wastewater samples from pig farm is shown in Table 5 and those of soil sample in Table 6. The highest significant correlations (p<0.05) for wastewater physicochemical parameters (Table 5) observed in this study were between Salinity and orthophosphate (positive correlation), and between BOD and temperature (negative correlation). The lowest insignificant correlation for pig farm wastewater physicochemical parameters (Table 5) observed in this study were between salinity and DO (positive correlation), and between TDS and nitrate (negative correlation). The highest significant correlations (p<0.05) for soil physicochemical parameters (Table 6) observed in this study were between orthophosphate and COD (positive correlation), and between orthophosphate and nitrate (positive correlation). The lowest insignificant correlation for soil physicochemical parameters (Table 6) observed in this study were between pH and nitrite (negative correlation), and between temperature and orthophosphate (positive correlation)

DISCUSSION

The pH values for wastewater samples (Table 1) and soil samples (Table 3) fell within the recommended limit of 6-9 (DWAF, 1996c; Government Gazette, 2012). The near neutral and alkaline nature observed for soil samples may be attributed to surface runoff or overflow of the observed alkaline wastewater. The pH values for wastewater and soil samples varied significantly (Table 2 and Table 4). High pH in soil and water systems altered the solubility of other chemical pollutants and caused the volatilization as well as microbial decomposition of organic acid. Thus, the subsequent release of ammonia through mineralization of organic nitrogen source (Singh and Agrawal, 2012) can be elevated due to high pH in soil and water systems. Low pH in soil can increase the availability of metals since hydrogen ions have the affinity for competing with metals ions and releasing them in soil solution for uptake by plants (Singh and Agrawal, 2012). Results were similar to those observed by Aguilar et al. (2011), where pH values of 6 to 8 was recorded for wastewater samples and 6.2 to 8.6 for soil samples from pig farm in this study.

The South African guideline for EC in wastewater and effluent that could be discharged into the receiving water system is 70 mS/cm and limit for soil EC is set at 2 mS/cm for the protection of plants and groundwater (Government Gazette, 2012). The variation of EC values for wastewater samples were insignificant (table 2) while EC values for soil samples varied significantly (p<0.05) at the monthly intervals (Table 4). This may be due to the low salinization and alkaline nature of soil and wastewater sample observed in all sampling sites.

High temperature affects the toxicity of some chemicals in the environment as well as the sensitivity of living organisms to toxic substances (Akan et al., 2008). Low temperature in soil slows the chemical and biological rate processes, while high temperature in soil affects seed germination, regenerates absorption and transport of water and nutrients (Roth et al., 2014). According to the South African standard for wastewater and effluent temperature, the limit was set at ≤25°C (Department of Water Affairs and Forestry (DWAF), Water Research Commission (WRC), 1995). Temperature for both soil and wastewater samples (Table 1 and Table 3) fell within

Table 3. Physicochemical parameters of pig farm soil samples.

Period	Sampling point	Parameters									
		pH	Temp. (°C)	Sal.(psu)	EC (mS/cm)	TDS (g/L)	COD (mg/L)	DO (mg/L)	PO_4^{3-} (mg/L)	NO_2 (mg/L)	NO_3(mg/L)
March	Enc-S	6.75±0.37	25.00±1.0	0.06±0.03	0.54±0.01	0.66±0.10	242.67±4.73	7.68±0.21	62.27±6.72	56.23±3.15	152.7±46.89
	Enc S-20m	7.2±0.03	13±0.0	0.03±0.01	0.48±0.0	0.49±0.02	258±2.15	7.91±0.1	53.61±0.07	46.37±0.67	79.5±0.57
	Enc S-100m	6.67±0.01	23±0.0	0.01±0.00	0.39±0.0	0.37±0.00	159±2.89	7.69±0.3	27.19±0.9	39.26±0.1	51±2.01
	CW S-20m	6.54±00	25.5±0.0	0.05±0.01	0.45±0.0	0.29±0.01	217±3.05	8.03±0.2	33.38±0.54	12.67±0.10	273.5±1.15
	CW S-100m	6.91±0.01	22±0.0	0.02±0.01	0.33±0.0	0.13±0.00	152±1.89	8.45±0.1	19.01±0.31	11.05±1.22	117.5±1.09
April	Enc-S	6.95±0.23	20.17±0.76	0.05±0.01	0.28±0.04	0.13±0.02	141.13±2.52	7.54±0.10	52.40±3.15	49.39±6.57	162.17±35.3
	Enc S-20m	7.4±0.03	13±0.0	0.02±0.00	0.22±0.0	0.16±0.01	108±3.75	7.61±0.1	40.50±0.1	29.77±0.2	87±2.06
	Enc S-100m	7±0.02	20±0.0	0.07±0.01	0.12±0.0	0.10±0.01	91±3.12	7.81±0.2	21.37±0.3	10.84±0.4	64.5±1.45
	CW S-20m	6.28±0.01	18.5±0	0.03±0.01	0.14±0.0	0.14±0.01	117±2.56	7.55±0.1	28.50±0.3	41.91±0.1	280.5±0.7
	CW S-100m	7.03±0.01	16±0.0	0.01±0.01	0.11±0.0	0.05±0.01	86±4.35	8.01±0.0	14.02±0.29	12.35±1.31	110.5±0.37
May	Enc-S	7.14±0.48	17.67±1.53	0.07±0.03	0.75±0.48	0.24±0.02	169.33±8.50	6.69±0.60	37.83±2.70	48.33±5.75	135±28.83
	Enc S-20m	7.07±0.01	13±00	0.06±0.00	0.43±0.0	0.16±0.00	118±4.32	7.34±0.2	26.8±0.08	31.00±0.1	77.5±0.72
	Enc S-100m	6.98±0.01	17±00	0.09±0.02	0.32±0.0	0.09±0.02	82±3.65	7.56±0.1	12.05±0.29	15.50±0.03	32.5±1.74
	CW S-20m	7.98±0.02	15±00	0.01±0.00	0.34±0.0	0.07±0.00	152±2.50	7.36±0.3	21.7±0.35	52.50±0.1	217.5±1.3
	CW S-100m	7.11±0.03	14.5±00	0.02±0.01	0.18±00	0.05±0.0	92±1.55	7.71±0.3	10.17±0.49	10.25±0.07	122.5±1.75
June	Enc-S	6.91±0.52	14.00±1.00	0.04±0.02	0.65±0.41	0.22±0.04	122.67±4.73	5.64±0.55	24.37±0.96	29±7.72	272.83±19.8
	Enc S-20m	6.97±0.01	13±00	0.01±0.00	0.33±0.0	0.14±0.01	98±2.56	7.14±0.3	13.1±0.36	13.9±0.10	135±1.10
	Enc S-100m	6.87±0.02	12±00	0.01±0.00	0.28±0.0	0.08±0.01	41±1.25	7.48±0.4	9.2±0.30	9.6±0.37	50±0.42
	CW S-20m	7.73±0.02	16±00	0.03±0.01	0.30±0.0	0.15±0.02	107±2.55	7.44±0.1	15±0.14	21±0.29	225±1.81
	CW S-100m	6.93±0.01	14±00	0.00±0.00	0.19±0.0	0.06±0.00	72±3.01	7.75±0.1	7.35±0.27	9.23±0.34	112.5±2.00
July	Enc-S	8.01±0.60	13.33±2.08	0.05±0.01	0.73±0.08	0.29±0.15	260.17±9.57	5.31±0.40	41.82±2.46	79.67±95.62	241.67±27.5
	Enc S-20m	7.41±0.02	13±00	0.01±0.00	0.42±0.0	0.11±0.01	140±2.43	6.02±0.1	21.7±0.58	17±0.13	130±1.15
	Enc S-100m	7.67±0.02	12±00	0.01±0.00	0.31±0.0	0.03±0.01	124±1.46	6.25±0.0	10±0.26	9.01±0.39	52.2±0.96
	CW S-20m	8.15±0.01	15±00	0.04±0.02	0.48±0.0	0.54±0.01	260±2.03	7.10±0.3	64±0.17	71±0.32	301.5±2.78
	CW S-100m	7.99±0.02	13±00	0.01±0.00	0.33±00	0.01±0.01	108±2.99	7.89±0.2	24±0.20	11±0.19	90±1.42
August	Enc-S	7.82±0.34	13.17±0.29	0.02±0.01	0.28±0.02	0.15±0.03	266±4.58	6.12±0.13	137.67±6.43	17.33±2.52	146.67±12.6
	Enc S-20m	7.76±0.01	13±00	0.01±0.00	0.21±0.0	0.09±0.01	140±3.45	6.69±0.2	45±0.09	19±0.51	80±1.66
	Enc S-100m	6.95±0.01	12.5±00	0.01±00	0.23±0.4	0.011±00	40±2.18	7.01±0.1	29±0.21	8±0.21	75±1.38
	CW S-20m	8.43±0.01	16±00	0.13±0.02	1.37±0.0	0.88±0.01	304±2.79	6.52±0.4	255±0.68	142±0.15	475±1.19

Table 3. Cont.

	CW S-100m	7.75±0.02	14±00	0.02±0.01	0.54±0.0	0.03±0.01	152±4.04	6.85±0.2	48±0.31	12±0.31	100±1.74
Standards		6.5-8	<40	≤0.2	≤2	≤500	≤ 200	≥ 5	≤ 5	≤ 13	≤ 120

Temp: Temperature; EC: Electrical Conductivity; TDS: Total Dissolved Solids; COD: Chemical Oxygen Demand; DO: Dissolved Solids; Ortho-P: Orthophosphate; NO_2: Nitrite; NO_3: Nitrate. All parameters are expressed in mg/L except for Temperature (^{O}C), Electrical Conductivity (mS/cm), Salinity (psu). Standards were adopted from FME and Government Gazette.

Table 4. The P-value and F-value for physicochemical parameters of pig farm soil samples.

P and F values	Parameters									
	pH	Temp.	Salinity	EC	TDS	COD	DO	Ortho-P	NO_2	NO_3
F values [a]	26.03	20.68	15.96	7.62	17.69	20.58	17.37	20.57	48.21	2.80
P values [b]	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.05*	0.00*	0.00*	0.02*
F values [c]	4.88	0.86	8.80	10.32	5.88	9.74	7.64	4.74	13.63	38.77
P values [d]	0.00*	0.53	0.00*	0.05*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
F values [e]	2.09	6.88	8.50	6.56	9.34	8.62	3.32	9.13	5.38	8.36
P values [f]	0.03*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*

Temp: Temperature; EC: Electrical Conductivity; BOD: Biological Oxygen Demand; TDS: Total Dissolved Solids; COD: Chemical Oxygen Demand; DO: Dissolved Solids; Ortho-P: Orthophosphate; NO_2: Nitrite; NO_3: Nitrate. *P<0.05 significant variation. Values are expressed in milligrams per litre except in pH, temperature (in degrees Celsius), salinity (in practical salinity unit), and EC (in micro-Siemens per centimetre), TDS (grams per litre). [a] F values for parameters and month. [b] P values for parameters and month. [c] F values for parameters and sampling point. [d] P values for parameter and sampling point. [e] F values for combined effect of month and sampling point on parameters. [f] P values for combined effect of month and sampling point on parameter.

the recommended limits of ≤25°C for wastewater to be discharged to water systems (DWAF, WRC, 1995) and for soil at ≤40°C for the protection of plants and groundwater (FME, 2011). This may be because samples were collected in the morning and atmospheric temperature (differed monthly due to seasons) never reached as high as 25°C during sampling periods. This explains the significant interaction effect of month and sampling point on temperature (Table 2 and Table 4) and indicates that temperature was not only a function of season but also dependent on sampling point. Thus, the observation of temperature values in this study implies that seepage temperature may not offset the homeostatic balance of the receiving environment.

The levels of BOD for wastewater samples (Table 1) exceeded the recommended limit of 40 mg/L set by FAO (1992) for agricultural purposes and varied significantly (Table 2). This may be attributed to the high use of chemicals at the pig farm that are organic or inorganic in nature and this can promote an increase in microbial growth and microbial degradation of organic or inorganic matter. High BOD values can cause greater oxygen demand in the receiving environment and thus leading to depletion of available oxygen to critical levels (Roth et al., 2014). BOD for wastewater samples observed in this study were lower than those reported by Vanotti et al., (2002) and were also higher than those reported by González et al., (2009).

TDS results for wastewater samples (Table 1)

Table 5. Correlation matrix of physicochemical parameters of pig farm wastewater samples.

	pH	*BOD*	*Temperature*	*EC*	*Salinity*	*TDS*	*DO*	*Turbidity*	*Ortho-P*	*COD*	*Nitrate*	*Nitrite*
pH	1											
BOD	-0.0503	1										
Temperature	0.2075*	-0.5933*	1									
Conductivity	0.0415	0.1173*	0.0064	1								
Salinity	0.0379	0.2685*	-0.1843*	0.2731*	1							
TDS	-0.1011*	0.0184	-0.0418	0.021	0.0359	1						
DO	-0.2956*	-0.582*	0.3268*	-0.0486	0.0017	-0.0219	1					
Turbidity	0.0266	0.0786	-0.1212*	0.0178	0.0687	0.0213	-0.088	1				
Orthophosphate	-0.0914	0.1827*	-0.1343*	0.2563*	0.6206*	-0.0091	0.1874*	0.0561	1			
COD	0.0512	0.3591*	-0.1856*	0.0269	0.3199*	0.0434	-0.1467*	0.0335	0.1472*	1		
Nitrate	-0.1561*	0.3184*	-0.218*	0.0423	0.176*	-0.0003	-0.2076*	0.0468	-0.0085	-0.0247	1	
Nitrite	-0.0543	0.171*	0.0905	-0.0489	-0.0961	0.055	-0.1921*	-0.012	-0.0475	0.0922	0.0647	1

COD: Chemical Oxygen Demand; BOD: Biological Oxygen Demand; TDS: Total Dissolved Oxygen; DO: Dissolved Oxygen; EC: Electrical Conductivity; Ortho-P: orthophosphate. -: negative correlation
*= P<0.05 significant variation

Table 6. Correlation matrix of physicochemical parameters of pig farm soil samples.

	pH	*Temperature*	*EC*	*Salinity*	*TDS*	*DO*	*0rtho-P*	*COD*	*Nitrate*	*Nitrite*
pH	1									
Temperature	-0.4*	1								
EC	0.1404*	0.1068*	1							
Salinity	-0.007	0.2909*	0.6358*	1						
TDS	-0.113*	0.5796*	0.3488*	0.5266*	1					
DO	-0.453*	0.4721*	-0.5026*	-0.2149*	-0.0658	1				
0rtho-P	0.2924*	-0.0650	-0.0889	0.0661	0.3472*	-0.1805*	1			
COD	0.3655*	0.1083*	0.3338*	0.2920*	0.5927*	-0.3851*	0.6897*	1		
Nitrate	0.1551*	-0.0994	0.1666*	0.5571*	0.1975*	-0.3276*	0.4373*	0.3679*	1	
Nitrite	-0.004	0.3241*	0.1625*	0.4737*	0.5120*	0.0577	0.6111*	0.4238*	0.5935*	1

COD: Chemical Oxygen Demand; BOD: Biological Oxygen Demand; TDS: Total Dissolved Oxygen; DO: Dissolved Oxygen; EC: Electrical Conductivity; Ortho-P: orthophosphate. -: negative correlation
*= P<0.05 significant variation

were higher than the recommended standards set by DWAF, (1998) which set the limit of ≤ 450 mg/L of no risk to aquatic life for seepage released into the receiving environment. TDS values for wastewater samples did not vary significantly (Table 2). This may be attributed to the possible presence of potassium chloride and sodium which are known to elevate TDS concentrations. High TDS can be toxic to freshwater animals by causing osmotic stress and affecting the osmoregulatory capability of organisms (Akan et al., 2008). The results obtained for soil TDS

(Table 3) were within the limits of ≤500 mg/L for the protection of ground water as set by FME and varied significantly (Table 4). Soil TDS was observed to be higher in March in enclosure soil (Enc S), and in July and August Soil 20 m from constructed wetland (CW S-20 m) as shown in Table 1, where TDS was recorded to be 0.66±0.10 g/L (March), 0.54±0.01 g/L (July), and 0.88±0.01 g/L (August). The significant difference ($P<0.05$) in soil TDS values observed in March (Enc S), July and August (CW S-20 m) may be responsible for the observed monthly variation.

The salinity results for wastewater fell within the acceptable limit of 33 psu to 35 psu of no risk for all biological activities in the marine ecosystem (Whitefield and Bate, 2007). Salinity for soil must not exceed 0.2 psu for the protection of plants and ground water (Government Gazette, 2012). Salinity levels in soil samples (Table 3) were within the recommended limits set by Government Gazette (2012). This may be due to the low EC observed in soil samples (Table 3). High salinity levels in water resources increases requirements for pre-treatment of water for selected seepage. This can cause serious ecological disturbance that may result in adverse effects on the aquatic biota (Oluyemi et al., 2006). High salinity in soil hinders plant growth by affecting the soil-water balance in soil. Salinity values for both soil and wastewater samples varied significantly (Tables 2 and 4). This significant variation may be due to salinity level at effluent, Enc S- 100 m and CW S-100 m which consistently remained lower as compared to other sampling points (Table 1 and Table 3). This may be caused by low EC observed at these sampling points as EC is a measure of salinity in the environment.

The COD results for wastewater samples (Table 1) fell short of the acceptable limit of < 30 mg/L as recommended by the South African government (Government Gazette, 1984). COD values for wastewater samples varied significantly ($P<0.05$) (Table 2). An elevated level of COD in water system leads to drastic oxygen depletion which adversely affects the aquatic life (Fatoki et al., 2003). High COD values observed in wastewater samples in June and July compared to other sampling months could be attributed to low degradation rate of organic matter due to low microbial activity due to cold temperatures. This is shown by the observed positive correlation between COD and temperature (Table 5). The results obtained for soil COD met the required limit of ≤ 200 mg/L for protection of ground water as set by Government Gazette (1984) except for CW S-20 m and Enc S in March, July, and August (Table 3). This may be attributed to surface run off or leaching of pig farm wastewater with high COD levels (Table 1). The COD values for soil samples varied significantly (Table 4). The significant variation may be attributed to COD values at Enc S and CW S-20 m and Enc S- 20 m were consistently high. This may be due to an increase in the addition of both organic and inorganic substrate leaching from wastewater emanating from Enc W and CW. High COD in soil causes soil fixation, resulting in lower availability of nutrients for plants (Chukwu, 2005). Similar results were also reported by Aguilar et al. (2011) where COD from pig farm seepage was recorded to be as high as 9960.83 mg/L due to low microbial activity caused by cold temperature.

Turbidity values for wastewater (Table 1) fell within acceptable limits of ≤5 NTU by DWAF (DWAF, 1996c). The variation in turbidity values in wastewater samples was insignificant (Table 2). Excessive turbidity in seepage can cause problem with water purification processes such as flocculation and filtration, which may increase treatment cost (DWAF, 1998). High turbid waters are often associated with the possibility of microbiological contamination and high load of organic and inorganic nutrients, as high turbidity makes it difficult to disinfect water properly (DWAF, 1998).

The results of DO for wastewater samples (Table 1) and soil samples (Table 3) fell within the acceptable limit (≥5 mg/L) of no risk for the support of aquatic life and protection of ground water (DWAF, 1998) except for Influent, CW, and Effluent in June and August (Table 1). This may be attributed to the high nutrient load in seepage which can be a contributing source of nutrient to the receiving environment (Akan et al., 2008). DO values vary significantly ($p< 0.05$) for both soil and wastewater samples (Tables 2 and 4). Dissolved oxygen is essential in maintaining the oxygen balance in the environment especially aquatic ecosystem (Fatoki et al., 2003). Low DO can negatively impact an aquatic life by increasing their feeding migration and thus, leading to loss of life (Environment Canada, 2001).

Nitrate concentration for seepage must not be exceeded by the acceptable limit of 20 mg/L set by (DWAF, 1996c) and FME has set the limit for soil nitrate at ≤ 13 mg/L for the protection of ground water. As observed in this study, both soil and wastewater samples (Tables 1 and 3) did not meet the required limit set by DWAF and FME. This may be attributed to high nutrient load due to surface run-off and leaching of wastewater with high nitrate concentration from pig farm on the surrounding natural environment. Nitrate values for both wastewater and soil samples varied significantly ($p<0.05$) (Tables 2 and 4). High nitrate levels may result in excessive nutrient enrichment in water systems (eutrophication) leading to loss of diversity in the aquatic biota, environmental degradation through algal blooms, oxygen depletion and reduced sunlight penetration (Canadian Environmental Quality Guidelines (CCME), 2006). Nitrite like nitrate is also a source of nutrition that could have negative impacts on aquatic ecosystems at elevated concentrations. The nitrite levels for wastewater samples (Table 1) fell short of the South African standard (<0.5 mg/L NO_2) for preservation of aquatic ecosystem

(DWAF, 1996c). Nitrite levels for soil samples (Table3) also did not fall within the limit of ≤ 13 mg/L as set by FME for protection of ground water. This nitrite levels for wastewater and soil observed in this study can put the aquatic ecosystems and ground water at risk of eutrophication. Nitrite values for both soil and wastewater samples varied significantly ($p<0.05$) (Table 2 and Table 4). Soil nitrite concentration at Enc S, Enc S-20m, CW S-20m exceeded the required limit and this may be caused by surface run-off or leaching from wastewater with high nitrate concentration of surrounding environment. Results for wastewater samples in this study were higher than those observed by knight et al., (2000). Results obtained in this study for soil nitrite were higher than those obtained by Roth et al., (2014).

Orthophosphate levels for wastewater samples (Table 1) observed in this study exceeded the standard of 30 mg/L (DWAF, 1996c) and orthophosphate levels for soil samples (Table 3) also exceeded the FME standard of ≤ 5 mg/L. This observed PO_4^{3-} level will promote growth of algae and suggest that seepage from pig farm is polluted and poses a serious threat to the aquatic biota and the ecosystem of the receiving environment in general. PO_4^{3-} values for both soil and wastewater samples in this study varied significantly ($p<0.05$) (Tables 2 and 4). High PO_4^{3-} concentrations in wastewater samples (Table 1) in April, May, and June as compared to other sampling months may be the cause of PO_4^{3-} concentration (44 to 88 mg /L) variation. High orthophosphate concentration increase algae and plant growth in aquatic systems. Orthophosphate concentration for soil samples ranged from 3.69 to 9.5 mg/g near pig farm's enclosure.

The correlation of the physicochemical parameter of water samples from pig farm is shown in Table 5 and those of soil sample in Table 6. In Table 5, the insignificant correlation between pH and salinity ($r = 0.038$) was caused by the almost neutral pH concentration observed in samples. The insignificant negative correlation between DO and salinity ($r = -0.121$) in soil and the positive insignificant correlation in water samples ($r = 0.002$) as shown in Table 5 and Table 6 indicates that DO concentration decrease with an increase in salinity levels as observed in this study which may be due to a high nutrient load in pig farm seepage.

Several studies have reported that EC and TDS are good indicators of salinity (Akan et al., 2008; Oluyemi et al., 2006). Correlation of EC and TDS ($r = 0.0211$) in water samples (Table 5) was insignificant in this study, while the correlation of EC and TDS ($r = 0.349$) in soil samples (Table 6) were significantly higher as compared to salinity. It is expected that seepage should be high in EC and TDS levels to promote microbial growth. The significant correlation of salinity and nitrates ($r=0.176$) in water samples (Table 5) indicates that the less saline seepage of nitrates can be attributed to the consistent high concentration of nitrate in pig enclosures and influent, as compared to other sampling points.

The insignificant correlation between salinity and turbidity ($r = 0.068$), TDS and turbidity ($r = 0.021$) in water samples (Table 5) shows that effluents released in the pig farm may be a source of turbidity in the receiving environment. However as observed in this study, there was no correlation between salinity and TDS in both soil ($r = 0.11872$) and water samples ($r = 0.035976$) (Tables 5 and 6). This may be due to the high concentrations in organic and inorganic nutrients in the pig farm seepage. The insignificant correlation of COD with EC ($r = 0.0270$), TDS ($r = 0.0434$), pH ($r = 0.0513$), DO ($r = 0.147$), in waters samples (Table 5) and the insignificant correlation of COD with salinity ($r = 0.086$) in soil samples (Table 6) was due to the high COD levels caused by high rate of organic breakdown of organic and inorganic nutrients in seepage. This study is still ongoing, and efforts to further determine the impact on the microbial diversity of natural environment in the vicinity of pig farm due to impacts of pig farm seepage on the physicochemical parameters of the natural environment are still in progress.

Conclusion

High BOD, COD, and TDS levels as observed in wastewater and soil samples in this study could constitute potential pollution problems to the natural environment since they contain organic compounds that will require large quantities of oxygen for degradation. High levels of PO_4^{3-}, NO_3 and NO_2 leads to the eutrophication of the natural environment, which was evident of organic matter infiltration occurring at pig farm. It is therefore concluded that the pig farm seepage caused negative impact on the receiving site and its environment due to depletion in available oxygen, increase solubility of heavy metals and increase toxicity of other chemicals. Pig farm seepage also caused an increase in the sensitivity of living organisms to other toxic substances in soil and water systems. Furthermore, pig farm seepage may cause osmotic stress to the natural environment and affects osmoregulatory capability of organisms, and may cause eutrophication of water systems and soil in the natural environment in the vicinity of pig farm. Thus, efforts are still ongoing to further determine the impacts of pig farm seepage on the microbial diversity in the natural environment in the vicinity of pig farm in ARC-API. If microbial diversity is determined, mitigation for preventing microbial contamination of natural environment in vicinity of pig farm can be effected to reduce degradation of the environment.

Conflict of interest

The authors have not declared any conflict of interest.

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