This study was conducted to investigate the toxic effect of Aluminum sulphate (alum). Nine Nubian goat kids were divided into 3 groups, each of three goats. Group 1 animals were the undosed controls. Test groups were given alum at dose rates of 1 and 20% respectively for groups 2 and 3 for a period of 10 weeks after an adaptation period of two weeks during which the animals were kept under ideal experimental conditions. Clinical signs were closely observed with postmortem and histopathological examinations. Chemical investigations included enzymatic activities of ALP, AST, CK, ALT and LDH and metabolic changes of albumin, urea, total protein, cholesterol, bilirubin, glucose and creatinine were detected. Fluctuations in electrolyte levels of Mg, Fe, Na, K, Ca and P were monitored together with hematological changes in Hb, PCV, RBCs and WBCs. Mortalities occurred to variable degrees irrespective to the dose level. On alum challenge, the test species showed clinical signs of low voice, inappitence, dullness, whitish salivation, watery diarrhea and also recumbency. On atomic absorption only the lungs kept residual alum, while the livers washed out the substance, maybe via bile. Notably oral dosing with alum caused changes consisted of congested liver with white spots, stiff-greenish lungs and inflammed empty intestines. The un-dosed group 1 goats showed a normal picture. On histopathology, alum-dosed group of goats showed necrosis in the cortex and medulla of the kidney in one group member, emphysema in the lungs and necrosis in the hepatocytes and congestion in the liver in all group members. On evaluation of the previous results, alum was considered toxic to Nubian goat kids at all tried dose rates. Practical implications of the results were highlighted as suggestions for future work were put forward.

Key words: Toxicity, alum, Nubian goats, drinking water.

INTRODUCTION

The treatment of waters to make them suitable for subsequent use requires physical, chemical and biological processes such as distillation, gas exchange, coagulation, sedimentation, filtration, adsorption, iron exchange and disinfection (WHO, 1984).

Polymer (polyDADMAC) is one of the synthetic cationic polyelectrolytes which are used widely in drinking water treatment (DWI, 2001, 2002) and historically dirty water is cleaned by treating with alum and lime. Despite the toxicity, alum is known to improve floc formation yielding a large size of fast-sitting rate, improves treated water quality through reducing suspended solids and turbidity, filter-runs, cost effective in use and is widely used to precipitate phosphate in industrial effluent treatment plant (AWWA, 1997).

In Sudan, the first use of chemicals to reduce the turbidity of the Nile water, especially during the flood season, to standardize it for the healthy human consumption with a maximum allowable level (MAL) of 150 mg/L, was at 1925 (Mohammed, 1998). The disposal system to eliminate the outcome of the chemical sludge that happen during treatment of the turbid water, is not adjusted well to the laws of environmental health regulations. Throughout the time alum did not give satisfactory results in the reduction of turbidity of water, especially during the flood season. As Sudan had tried comprehensive drinking water treatment using alum for ages and considering the lack for toxicological data in this area, this experiment was done to explore the risk factor by testing alum in goats for toxicological effects.
MATERIALS AND METHODS

Animals, housing and management

Nine male Nubian goat kids (5 to 7 months old) were purchased from El Sheikh Abu Zeid, a local livestock market in the vicinity of Omdurman and kept within the premises of the Veterinary Teaching Hospital, Faculty of Veterinary Medicine, University of Khartoum. During the 2-week adaptation period, animals were ear tagged and given prophylactic doses of Oxytetracycline 5% (Bremerpharma, Germany) and Sulphamethazine 33.3% (Norbrook, U.K.) against bacterial infections and coccidiosis respectively and fed ad libitum on lucerne and allowed free access to Nile water.

Administration and dose levels of alum

At the end of the adaptation period, animals were weight-distributed, and allotted randomly to three groups, each of three goats. Goats of (Group 1) were left undosed (controls).

Goats of (Group 2) were treated daily (by the oral route) with alum in concentration of 1% in drinking Nile water while goats of (Group 3) were given alum in a concentration of 20%. Goats of (Group 1) were left undosed (controls).

Parameters

Clinical signs and mortality rates were recorded. Blood samples were obtained from the jugular vein before the start of the experimental dosing and thereafter fortnightly for haematological investigations and serum analysis.

Haemoglobin concentration (Hb), packed cell volume (PCV), red blood cell (RBC) and white blood cell (WBC) counts were estimated.

Sera were analyzed for the activities of ALP, AST, CK, GPT and LDH and also for the concentrations of metabolic indicators cholesterol, creatinine, bilirubin, uric acid, urea, albumin, total protein and glucose and also electrolytes calcium, inorganic phosphorus, iron, sodium and potassium.

METHODS

Haematological methods

These methods were described by Schalm (1965). Blood samples from goats were collected into clean dry bottles containing the anti-coagulant heparin from the jugular vein. The concentration of haemoglobin was determined by the cyanmethaemoglobin technique by Drabkins solution in g/dl of blood. Fresh blood samples were centrifuged in a micro haematocrit centrifuge to read off the packed cell volume percentage. Blood cells and the white blood cells were counted with an improved Neubauer haemocytometer (Hawksley and Sons Ltd., England).

Histological methods

The specimens were collected immediately after death or slaughter and fixed in 10% formal saline, embedded in paraffin wax, sectioned at 5 µm and stained with haemotoxylin and eosin (H & E) using Mayer's haemalum.

Chemical methods

Blood samples were obtained from the jugular vein before and after dosing with AlSO₄. Venous blood samples were centrifuged at 3000 r.p.m. for 5 min and stored at -20°C until analyzed for LDH, AST, ALP, CK, cholesterol, creatinine, total bilirubin, urea, total protein, calcium, albumin, phosphorus, iron and magnesium by a colorimetric method using a commercial kit (Randox Laboratories Ltd., U.K.).

Determination of Na⁺ and K⁺

Samples were diluted in 100 ml of distilled water compared with Na⁺ and K⁺ standard (Sherwood Scientific Ltd. UK) with concentration of 140 and 50 mmol/l respectively. Concentrations were detected by Flame, using Bio-dynamics Lyteteck Flame Photometer, USA.

Statistical methods

The difference between mean values of data were analysed by the un-paired students- t-test (Snedecor and Cochran, 1989).

RESULTS

Clinical signs

The most obvious signs in the 1% alum-dosed goats included low voice, nervous signs, inappetence, recumbency and death. The 20% alum-dosed goats showed watery involuntary diarrhea followed by dullness, shivering, salivation, inappetence, isolation from the herd and final recumbency, with a 100% mortality rate. Deaths started in the 1% alum-dosed goats in the 9th day up to the 13th, while that of the 20% alum-dosed goats started at the 1st day up to the 5th day of treatment. The control undosed goats (group 1) were normal.

Post-mortem changes

In the 1% alum-dosed group of goats, changes consisted of congested liver with white spots, stiff-greenish lungs and inflamed empty intestines. On post-mortem of the 20% alum-dosed group of goats, most livers were congested and were spotted with white foci, lungs were stiff and greenish and intestines were inflamed and empty. The un-dosed group 1 goats showed a normal picture.

Histopathological picture

On histopathology, the 1% alum-dosed group of goats showed necrosis in the cortex and medulla of the kidney in one group member, emphysema in the lungs and necrosis in the hepatocytes and congestion in the liver in all group members (Figure 1).

Lung sections of the 20% alum-dosed group of goats showed emphysema and the intestines were edematous with catarrhal inflammation, hearts slightly necrotic, spleens slightly congested and the liver showed degenerative necrosis and lymphocytic infiltration. No
abnormal histopathological changes were observed in the un-dosed group of goats.

**Changes in the activities of serum enzymes**

Table 1 shows the changes in serum constituents of goats treated with alum.

Clearly decreased values (P<0.05) were observed in both test groups when their serum activities of ALP and AST were evaluated. Values of CK, and ALT were higher (P<0.05) when compared to the control, and these values were highly (P<0.001) increased for LDH compared to the control. The control group showed normal activities of the serum enzymes.

**Serum metabolites values**

Table 2 summarizing the changes in serum metabolite in blood of goats treated with alum. Both test groups values for albumin, total protein, and cholesterol, were found significant in comparison to the un-dosed group, while significant increases (P<0.01 to 0.001) were observed when the urea serum level was evaluated. Marked increases (P<0.05 to 0.01) were detected on evaluating creatinine. Goats of group 2 and 3 showed significant increase and decrease (P<0.05) when investigating both bilirubin and glucose respectively, when compared to the control group 1 which showed values that were within the normal ranges for all the metabolites tested.

**Changes in serum electrolytes**

The changes in serum electrolytes are summarized in Table 3. Significant decreases (P< 0.01) in magnesium concentrations were seen in both groups. Goats of group 2 and 3 showed significant decreases (P<0.05 to 0.001) in their serum iron, sodium, potassium, and phosphorus, whereas for Ca, group 2 estimates were insignificant (P>0.05) and group 3 estimates were decreasingly

![Figure 1. Necrosis in the hepatocytes of goats dosed with 1% alum in drinking water (H & E) X 100.](image-url)
Table 2. Average values (mean ± SD) of serum metabolites of the alum-dosed goats.

<table>
<thead>
<tr>
<th>Group / Dose</th>
<th>Albumin (g/dl)</th>
<th>Urea (mg/dl)</th>
<th>Total protein (g/dl)</th>
<th>Cholesterol (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 (un-dosed)</td>
<td>3.01 ± 0.37</td>
<td>35.35 ± 4.37</td>
<td>5.47 ± 0.75</td>
<td>38.10 ± 3.59</td>
</tr>
<tr>
<td>G2 (1% solution)</td>
<td>3.92 ± 0.27 NS</td>
<td>76.70 ± 1.42 NS</td>
<td>4.12 ± 1.21 NS</td>
<td>40.82 ± 10.78 NS</td>
</tr>
<tr>
<td>G3 (20% solution)</td>
<td>3.17 ± 0.40 NS</td>
<td>75.47 ± 8.19 NS</td>
<td>3.56 ± 0.60 NS</td>
<td>34.57 ± 6.28 NS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group / Dose</th>
<th>Bilirubin (mg/dl)</th>
<th>Glucose (mg/dl)</th>
<th>Creatinine (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 (un-dosed)</td>
<td>0.18 ± 0.13</td>
<td>31.08 ± 0.87</td>
<td>0.21 ± 0.04</td>
</tr>
<tr>
<td>G2 (1% solution)</td>
<td>0.84 ± 0.15*</td>
<td>5.93 ± 10.28*</td>
<td>0.50 ± 0.16**</td>
</tr>
<tr>
<td>G3 (20% solution)</td>
<td>0.89 ± 0.14*</td>
<td>6.11 ± 1.53*</td>
<td>0.44 ± 0.05*</td>
</tr>
</tbody>
</table>

NS = Not significant * denotes P<0.05 ** denotes P<0.01 *** denotes P<0.001.

Table 3. Average values (mean ± SD) of serum electrolytes of the alum-dosed goats.

<table>
<thead>
<tr>
<th>Group / Dose</th>
<th>Mg (mg/dl)</th>
<th>Iron (µg/dl)</th>
<th>Na (mg/dl)</th>
<th>K (mg/dl)</th>
<th>Ca (mg/dl)</th>
<th>P (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 (un-dosed)</td>
<td>1.44 ± 0.08</td>
<td>228.77 ± 13.73</td>
<td>152.53 ± 0.42</td>
<td>5.69 ± 0.12</td>
<td>6.92 ± 1.44</td>
<td>4.14 ± 0.11</td>
</tr>
<tr>
<td>G2 (1% solution)</td>
<td>0.70 ± 0.01**</td>
<td>165.87 ± 0.31*</td>
<td>121.80 ± 0.36**</td>
<td>5.03 ± 0.01**</td>
<td>3.70 ± 0.01 NS</td>
<td>2.21 ± 0.50**</td>
</tr>
<tr>
<td>G3 (20% solution)</td>
<td>0.27 ± 0.02**</td>
<td>62.60 ± 4.68**</td>
<td>30.73 ± 0.46***</td>
<td>1.34 ± 0.02***</td>
<td>1.11 ± 0.03*</td>
<td>0.59 ± 0.07***</td>
</tr>
</tbody>
</table>

NS = Not significant * denotes P<0.05 ** denotes P<0.01 *** denotes P<0.001.

Table 4. Average haematological values (mean ± SD) of the alum-dosed goats.

<table>
<thead>
<tr>
<th>Group / Dose</th>
<th>Hb (g %)</th>
<th>PCV %</th>
<th>RBCs (x10⁶)</th>
<th>WBCs (x10⁶)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 (un-dosed)</td>
<td>8.13 ± 0.57</td>
<td>26.40 ± 1.97</td>
<td>8.57 ± 0.87</td>
<td>6.36 ± 0.67</td>
</tr>
<tr>
<td>G2 (1% solution)</td>
<td>7.18 ± 1.29 NS</td>
<td>22.53 ± 0.70**</td>
<td>4.96 ± 0.01**</td>
<td>7.80 ± 0.01 NS</td>
</tr>
<tr>
<td>G3 (20% solution)</td>
<td>7.37 ± 0.66 NS</td>
<td>20.11 ± 0.19**</td>
<td>4.67 ± 0.59**</td>
<td>7.67 ± 1.97 NS</td>
</tr>
</tbody>
</table>

X NS = Not significant - denotes P<0.05 ** denotes P<0.01 *** denotes P<0.001.

significant (P<0.05). The serum levels of the aforementioned electrolytes in the control group were normal.

Haematological values

Table 4 shows the haematological values of goats dosed with alum. Concentrations of haemoglobin of both test groups were not deviated (P>0.05) from those of the control group, while those of PCV and RBCS were decreased (P<0.01). WBCS counts significantly decreased (P<0.01) in group 3, while counts of WBCS of group 1 and 2 were not different (P>0.05) compared with the control group goats which were of normal values.

DISCUSSION

Daily routine dosing of alum revealed marked nervous system involvement including frenzies, salivation, shivering involuntary watery diarrhea and finally recumbency (Verstraeten et al., 2008). The whole picture was showing a parasympathetic involvement (Orshoven et al., 2006) whereas the low voice was indicating the local irritant effect of alum on the vocal folds (IDSP, 1980; Barthold, 1996). In addition to the high rate of mortality in ruminant animals, the necrotic intoxicated lung, proved on atomic absorption of the processed liver - alum values were negligible, showed decreased activity in alkaline phosphatase (ALP) in serum as well as the absence of bilirubinaemia which suggests that alum is not expected to interfere with the excretory ability of the liver cells (Ford, 1963; Aspenstrom-Fagerlund et al., 2009). Necrotic hepatocytes in combination with the rise in some serum activity are suggests hepatocellular damage (Adam et al., 1973; Dafalla and Adam, 1986; Dafalla et al., 1987; Ayed et al., 1991; Kew, 2000). Renal insufficiency was indicated by increase in urea,
creatine, total protein, decrease in albumin concentrations and necrotic, haemorrhagic injured renal tubules (Ahmed and Adam, 1979). Intestinal wall which was spotted with white (probably with alum causing focal enteritis) was greatly affected with the irritant alum and/or its metabolites. When the resin is precipitated by alum in its preparation, commonly the salt intensifies its action and the cream of tartar increases the hydragogue effect (Felter, 1922). This action was very clear on the congested mesenteric blood vessels and symptomatically, by diarrhea and salivation due to nausea. Increased rates of mortality, are proportional with the dose of alum in test goats, may be due to myocardial and nervous system (CNS) involvement (mostly the parasympathetic). Pulmonary haemorrhages, oedema, emphysema, necrosis and adhesions may cause the clinically observed difficulty in respiration which was considered as one of the irritant effects of the toxicant and/or its metabolites. Hepatic damage was manifested in the congested and necrotic central vein, fatty changes, increased level of bilirubin, increased activities of liver enzymes in the serum (Ford et al., 1972; Adam, 1972; Adam et al., 1973). The irritant substance or its metabolites were incriminated for GIT affections manifested as nausea, salivation, vomiting, watery diarrhea and necrosis of *muscularis mucosae* (Orshoven et al., 2006). The same effects may also be due to increased peristaltic movement, cholinesterase deficiency. The additive effect of the increased creatinine, polymer and/or its metabolites, is indicating renal insufficiency. The development of suppression in the immune system of the poisoned goats. The haemorrhage and necrotic kidneys that were caused by the direct irritant effect of the polymer and/or its metabolites, is indicating renal insufficiency. The additive effect of the increased creatinine, urea AST concentrations in serum indicated damage to renal tubules. The available results and the studies of Mohamed and Adam (1992) and Ahmed and Adam (1979) suggested that serum urea level was of significance in the evaluation of renal toxicity in goats.

Alum is neurotoxic, cardiotoxic and lethal chemical in overdoses, a hepatotoxic, neuro toxic and nephrotoxic chemical even in mild overdoses. It can be deposited in lungs, the dose used routinely + 1.5 mg/l is also toxic.


Iowa State University Press, pp. 158-160.